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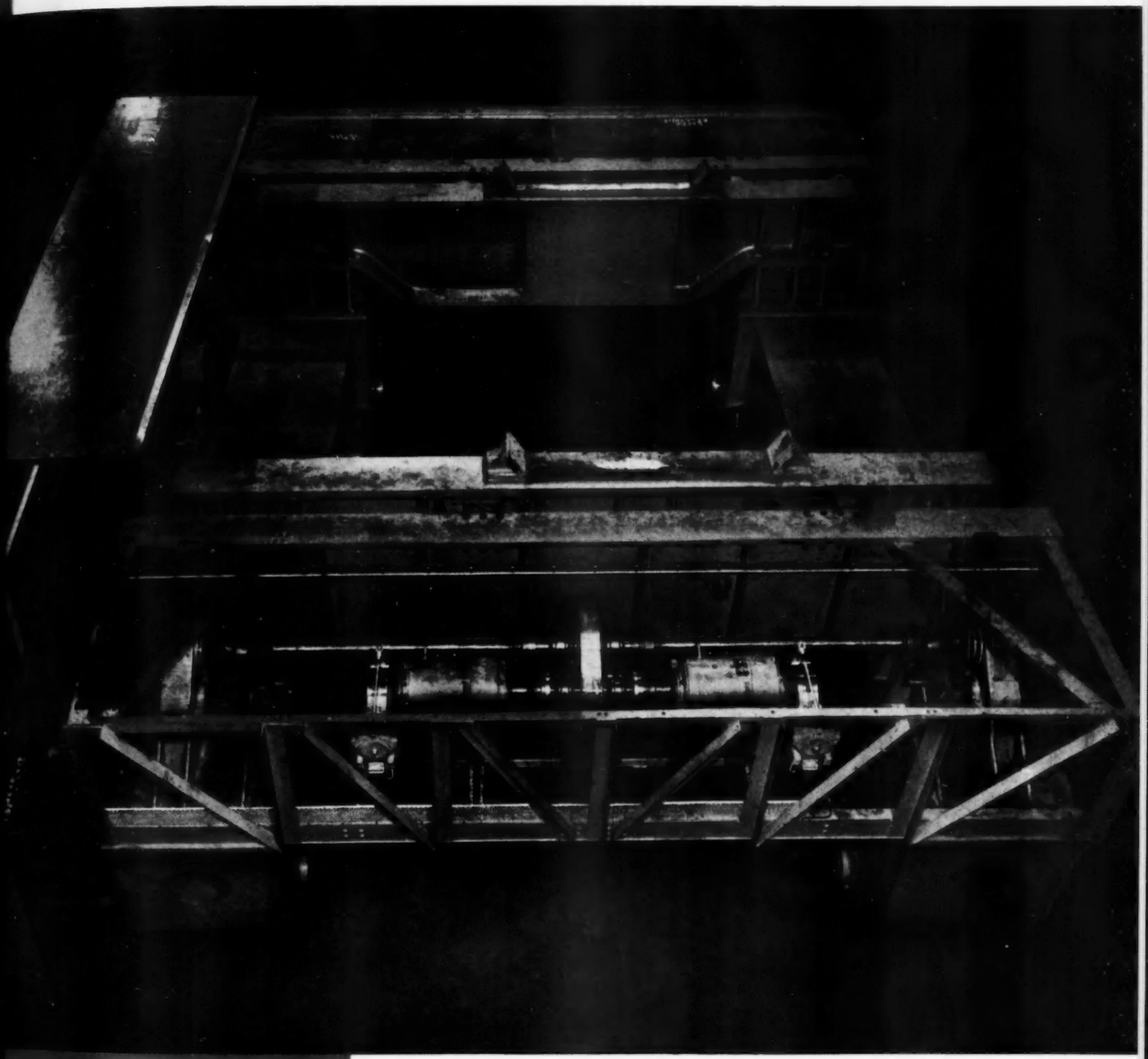

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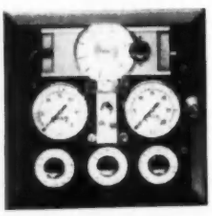

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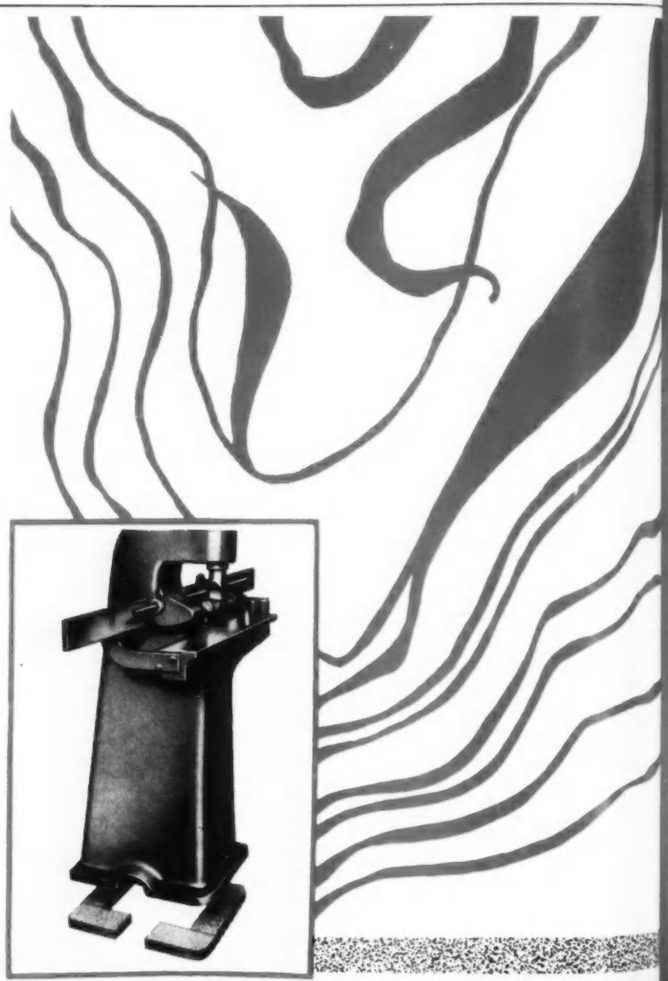

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THE ENGINEER

No. 5509 AUGUST 25, 1961 Vol. 212

ESSEX WATER SUPPLY

The issue early this week of the third of the hydrological surveys of river basins in the United Kingdom verifies once again the opinion held by many water supply engineers that the organisation of water supply in this country urgently needs modification. Previous surveys have covered the Great Ouse and the River Severn basins. The present one covers the Essex rivers and the Stour basin. The region surveyed is one of the driest in the country. For that reason it is also one of the regions in which the irrigation of crops is being increasingly practised. The population is expanding and new industrial plants are making demands for water. The bald fact is revealed by the survey that if the region were to attempt to rely solely on its own resources there would be a deficiency of some thirty million gallons a day by 1980 below an estimated demand of 158 million gallons per day. That estimate, moreover, makes only a moderate allowance for the expansion of crop irrigation. To quote from the Report itself "Should the necessity arise to expand irrigation to cover the whole of the irrigable area the water resources . . . would be hopelessly inadequate. Vast quantities of water would have to be imported from areas which enjoy generous rainfall, or be produced by the demineralisation of sea water on a grand scale. At the present time neither of these expedients can be considered economically viable".

Part of the estimated deficit, amounting to perhaps as much as ten million gallons a day, might be met by the more extensive re-use of water. Much sewage, for example, is at present discharged to the sea, whereas it could be properly treated and returned to rivers. However, there is the difficulty that the effluents would contain nutrients promoting the growth of algae, thereby complicating the production of a wholesome water supply. It is of no use to look to underground sources for help; they are overdeveloped already. Fully to develop surface water resources will necessitate the construction of a number of new impounding reservoirs. Objections can be found to almost every suitable site. There are also possibilities of increasing the yield by a "system of comprehensive control and distribution in which surface and ground water sources are made complementary to each other". But the conclusion is inescapable; "the area will have to look for additional supplies of water beyond the hydrometric boundaries".

The conclusion can be drawn that if the water resources of the region are to be developed to the full without damage to amenities and with due regard for the interests of all who use the rivers then there should be some authority for water supply controlling the whole region. Some existing water undertakers in the region are already in negotiation with the Metropolitan Water Board of London about a supply of water. Such negotiations could surely be carried on more satisfactorily were there a single authority for the whole region. It is satisfactory to realise therefore that the Minister is known to have sent to interested parties a document setting out a plan for the re-organisation of water supply under authorities for whole river basins and that he apparently contemplates bringing the River Boards into the picture. But even the resources of the M.W.B. could be overstrained were the use of irrigation to expand in Essex. Moreover, there are other regions, especially in the east of England, which within a few years will need to look outside their own boundaries for water supplies. The basin of the Great Ouse, already surveyed, is one of them. To many water engineers having in mind a general picture in the future of the movement of water across England from the wetter West to the drier East it seems that there should also be some central authority besides the regional water authorities for each basin. We agree with them. We do not see how regional authorities or the Ministry can be expected to study adequately the economic and constructional problems involved, or build the necessary aqueducts and create some kind of water grid. But the setting up of single authorities for whole basins would be a welcome step in the right direction.

OIL-FIRED POWER STATION FOR FAWLEY

As reported on page 335 of this issue the Central Electricity Generating Board has decided to apply to the Minister of Power and to the local planning authority for consent to the building of an oil-fired power station at Fawley, on Southampton Water. This proposal illustrates the Board's philosophy of a three-fuel economy for electricity generation. As explained by Sir Christopher Hinton at a Press Conference two years ago, electricity generation by the C.E.G.B. for the foreseeable future will be based on the economic and judicious use of coal, oil and nuclear fuel.

The proposed oil-burning station at Fawley fits logically into this concept. A statement made in December

1960 outlined the Board's views, bearing in mind that, while the national demand for electricity is growing by 7 per cent annually, the demand in the southern counties is increasing much more rapidly—at an annual rate of 10 per cent. These demands could be met by building power stations either on the south coast near the load centres or on the midlands coalfields, with transmission lines to the south. To minimise the mileage of transmission lines the Board was inclined towards the first alternative. Both nuclear and fossil-fuel-burning power stations were considered. Between Dungeness and Weymouth only two potentially promising sites for feasible nuclear power stations were found: one at Earley and the other at Hamstead on the Isle of Wight. After detailed investigations the former was rejected on technical grounds, while the Hamstead site proved to be technically excellent. However, the Board, appreciating the amenity value of the West Solent and realising that the psychological impact of a nuclear station at Hamstead might be unfavourable, decided to defer any decision about seeking consent to use the site. Further investigation of the alternative conventional stations demonstrated the economic advantages of oil firing on a site adjoining the Fawley refinery.

As to the reasons for the choice, we fully appreciate the Board's concern about the preservation of amenities and we wish that all other interests, both small and large, showed equal concern. We also realise that the Board's thinking on this subject is inspired by enlightened self-interest rather than pure altruism. But it would be unfortunate if the impression gained currency that the amenity question was becoming a psychological obsession and that the Board's planning always started from a defensive position. In the present instance, surely the choice between a nuclear power station at Hamstead and an oil-fired station at Fawley was decided mainly on its technical and economic merits. The Fawley project is the right one in the present circumstances because it is fully consistent with the practice of a three-fuel economy for electrical generation.

TRACTION MOTOR TROUBLES

Another setback to the British Railways programme of high-voltage a.c. electrification is the postponement of full electric services on the Fenchurch Street to Tilbury and Southend lines of the Eastern Region. Modifications to the traction motors in the rolling stock built for this service are said to be necessary to ensure complete reliability of the machines in service. Instead of full electrification this year, some electric trains will be introduced this autumn, running to steam train timings and interspersed with the steam service. After last year's misfortunes in Glasgow and on the North East London suburban lines, caution in putting equipment into traffic if there is any suspicion of trouble developing is understandable. The puzzling feature here is that the rolling stock concerned has been operating since 1959, first on the Colchester–Clacton 25kV "proving ground," then on the Liverpool Street–Shenfield–Southend lines after their conversion to 6·25kV a.c., and finally on the North East London routes to replace other sets which developed faults when those services were inaugurated last November. The trains now concerned are the 112 four-car units equipped by The English Electric Company Ltd., which are fitted with conventional d.c. motors with a one-hour rating of 274 h.p. at 620V, 340A. Their final destination has always been the Southend via Tilbury line, and their interim employment on the Clacton and Shenfield routes was part of the programme announced by the Eastern Region some years ago for changing over to a.c. electrification with minimum delay. On the Shenfield line, for example, they have enabled the 1500V d.c. stock to be withdrawn for conversion without reduction of services.

The nature of the trouble which has shown itself has not been precisely specified, although mention has been made of an insulation weakness, and the manufacturer confirms that later equipments embodying a "new manufacturing technique" developed since the earlier ones were supplied have proved entirely satisfactory. What, then, has shown up the weakness at this eleventh hour? Were it not for the emphatic statement that voltage surges and other phenomena associated with the British Railways dual-voltage a.c. system have nothing to do with it, it would be reasonable to draw parallels with what happened last year to the trains equipped by the G.E.C. These, too, ran without trouble on the 25kV Clacton lines, but on transfer to the North East London section, mainly electrified at 6·25kV, experienced breakdowns of insulation in traction motors and auxiliary rectifiers. They did not have the intervening period of running between Liverpool Street and Southend, also a 6·25kV section, but in comparison with other working on the a.c. system this route has a clean record. Why this should be so is not clear. Its only evident difference from others is that it has retained the heavier d.c. contact system, suitably insulated for the a.c. supply.

Happily the present difficulties are less serious than previous ones on the a.c. system and it has not been necessary to take trains out of service. Experience both on the Liverpool Street and Fenchurch Street lines, however, has shown the need for modifications and a priority programme is under way to this end. It will not be necessary to disrupt train services or to modify all the motors. Although less serious technically than previous episodes, however, the gravity of the situation must not be glossed over. A long-awaited improvement affecting a highly-populated outer suburban zone has been deferred indefinitely. No date has been given for introducing the full electric service expected this year, and although next June has been mentioned it was as a hope rather than a promise. A final report is still to come on the train equipment failures last year on the Glasgow and North East London lines. Its terms of reference might well be extended to throw more light on the present troubles.

REPORT ON THE GAS INDUSTRY

In its recently issued report on the gas industry the Select Committee on Nationalised Industries states quite bluntly that if gas is to hold its position as a fuel it is crucial that the cost of production should be reduced. A reduction of about 30 per cent in costs should be made quickly and on a large enough scale to have an early effect on the national price of gas. The best chance of achieving a substantial reduction in cost by all gas boards, it is considered, lies in large-scale production on a national basis backed by a national grid and helped by underground storage. In pointing out its belief that the decentralised structure of the gas industry is no longer adequate to meet the needs of the present situation, the committee advocates integration at national as well as area level to enable the industry to attain potential economies. To this end it recommends the establishment of a further Board, which would be given

powers and responsibility for the generation of gas by large-scale processes and for its distribution to areas. Its function for gas would be similar to that performed by the Central Electricity Generating Board for electricity supply.

It is indicated in the report that the main reason for recent rises in costs of gas production is the fact that the price of coal for the gas industry has risen more than that used by the electricity industry and much more than the price of oil. In this connection the report brings to light the "wintry" relations between the Gas Council and the National Coal Board—and the hope is expressed that the current joint study in connection with the Lurgi process may reconcile the viewpoints of the two industries and lead to a closer understanding.

We have mentioned only a few of the many points made in what is in fact a lengthy and detailed report. But one subject to which we think greater prominence should have been given in the report is that of research. The Committee comments that even now, at its peak, expenditure on research is too low. How very true! For an industry with the turnover of the gas industry to spend only an estimated £1,325,000 on research in the year 1960-61 may well explain in a large measure why its production costs are too high. Research is, however, beginning to be pressed more energetically and the fact that relatively recently a development and planning section and a Basic Research Group have been set up may be somewhat reassuring. For if the problem of how to get gas cheaply is to be solved surely greater efforts and more money should be directed towards fundamental and applied research to achieve these ends. Reorganisation of the industry may be necessary administratively, but prosperity will return to the industry only if means of improved production are developed and applied to promote internal economy and reduce costs to the consumer. The more important problems needing solution seem to us in fact to be technical rather than administrative.

LINES AND COLOUR

Pending publication of the Pilkington Committee's report next year, the future line standards for television in this country remain uncertain. Most manufacturers are preparing for 625 lines by introducing "switchable" receivers as distinct from "convertibles" which would need greater modification in the event of a change from the 405-line standard. The National Radio Show at Earls Court this week shows many of these "switchable" sets which are sold complete with the circuitry and selective switching for both standards, except for the u.h.f. tuner which presumably would be needed for 625-line transmissions. Usually this is a plug-in unit which could be added when necessary without modifications to existing wiring. The fact that it is not there already is simply because the frequencies to be allotted are not yet known. On all sides the visitor to Earls Court has opportunities to compare 405-line and 625-line pictures, and he is likely to find that the difference between them is less clear-cut than he has thought.

Colour is another live issue at Earls Court this year. The show marks the twenty-fifth anniversary of the first public showing of black-and-white high-definition TV at the Radio Exhibition of 1936, then held at Olympia. This year the B.B.C. is transmitting "live" colour features and film from a studio in the building, and demonstrating reception on colour and black-and-white sets in the "Colour Concourse". It may be remembered that the Television Advisory Committee's report in 1960 concluded, among other things, that the u.h.f. bands IV and V must be brought into use if television policy favours a change on merits from 405-line to 625-line standard; and that the question of line standards for these bands should be determined before a decision is reached on colour. These are among the questions now being considered by the Pilkington Committee. In the meantime The General Electric Company Ltd., has set forth the advantages, as it sees them, of the retention of 405 lines, both in statements to the press and in literature distributed at a "New TV Show" held at the New Horticultural Hall, Westminster, from August 19 to 24. Demonstrations at the show enabled the public to compare not only the two line standards, but also two colour systems—the American N.T.S.C. and the French SECAM, the latter being developed by the G.E.C. in collaboration with the Compagnie Française de Télévision. In favour of 405 lines it was argued that in practice picture quality does not depend only on definition, and that u.h.f. transmission problems may more than offset the advantage in this respect of 625-line signals. With regard to the SECAM system itself, attention was drawn to its comparative freedom from the colour distortion which may occur through phase variations on microwave links. Such questions of line standards and colour systems have given the television-viewing public plenty to think about in the past ten days. Some uncertainties cannot be resolved by the publication of reports. Colour television is still at the stage where a development such as a new form of colour tube might require a new system for transmitting the signal.

The Engineer—100 Years Ago (AUGUST 23, 1861)

"THE LOCK TRADE"

"The lock-trade in the common descriptions is in a most miserable condition. So severe is the competition of the smaller makers that the manufacturers who employ a large number of men, and who produce a superior article, have been compelled to reduce their prices. This is especially observable in the 10in stock lock. It will be scarcely credited that so low are the prices for this article now ranging, that a well finished unexceptional stock lock is being sold to the factors by makers of repute at 1s. each! It is a fact that at this price the manufacturers profit is only 1½d. a dozen! Padlocks are equally low. A ponderous lock and key is being supplied to the factors at 1s. 2d. a dozen. These, with others that the maker charges only 8½d. a dozen for, are now being sent out from Wolverhampton to the South African market. In first-class locks, however, the improvement of last week is more than maintained. For instance Messrs. Chubb and Son are now very much pressed to execute an order that they have just received, and that has been some time in the market, in which the price is £3 4s. per lock. At this price some 214 locks are required."

Industrial Value of D.S.I.R. Research—No. III*

FOREWORD: Engineering is essentially a practical business in that the products of the engineering industry are real things useful in one way or another to mankind. Yet, by contrast, the products of engineering research (as opposed in the present context to development) are usually ideas expressible only on paper in words, in mathematical equations, by drawings, or by diagrams. Such products can attain a real value only if they are applied by designers, manufacturers, or users of engineering devices. To what extent, then, is the work done at research laboratories in fact applied by more practical engineers? It is the object of this series of articles to throw some light on that question. The inquiry is confined to D.S.I.R. establishments; and the method is to select certain papers published by such establishments and to ask a number of firms whether they have made use of the information and, if so, to what extent design, or manufacture, has been altered thereby. The subject selected for this inquiry was work in connection with machine tools at the National Engineering Laboratory.

THE subjects selected for our inquiries for this the third in this series of articles relate to investigations carried out at the National Engineering Laboratory at East Kilbride on the use of hydrostatic transmission for driving machine tools ; and the impact extrusion of steel. These subjects seemed at the time to be particularly suitable because the investigations into hydrostatic machine tool drives have recently shown promise of interesting applications in industry ; and research into the impact extrusion, which is necessarily long term, will continue initially with the emphasis on steel.

Turning to the published reports on the subjects, the use of hydrostatic drives for machine tools formed the basis of an article by Mr. D. Firth (*Engineering*, June 17, 1960), and a vertical boring mill equipped with such a drive aroused manufacturers' interest when it was shown at the International Machine Tool Exhibition at Olympia in June last year and again at the Engineering, Marine, Welding and Nuclear Engineering Exhibition this year. Impact extrusion of steel has been the subject of many reports, one of the most recent of which is " The Extrusion of Metals : Steel under Cold Impact Conditions," by J. McKenzie and A. R. Rodger (N.E.L. Plasticity Report No. 163).

Use of Hydrostatic Drives For Machine Tools

Research into the use of hydrostatic drives for machine tools was undertaken because it was considered that, although comparatively low-powered equipment of that type was already being used on machines, it theoretically had many advantages which might be well applied advantageously to main power drives interlinked with the feed drives. The equipment used for the investigations incorporated a pump and motor of similar design based upon the N.E.L. " ball " type transmission, although a system might well use conventional pump/motors available on the market. The N.E.L. pump/motor units are of radial cylinder design in which standard steel ball bearings serve as plungers. The pumping action is imparted by the balls moving in a race eccentric to the driving axis provided by a pintle valve. Variable displacement is effected by moving the eccentric relative to the shaft centre. By using the variable displacement properties of both pumps and motors in a transmission system a wide stepless range of speeds is achieved with constant torque over the full range.

To ascertain the practicability of this form of transmission when actually applied to a machine tool the drive and control gear of the old vertical boring mill shown on Fig. 1 were removed and replaced by hydrostatic equipment. The main drive motor pump unit is fitted on the rear of the machine and the faceplate, through its internal gear ring, is driven by two hydrostatic motors. In operation these two motors have a common feed of pressure fluid but different displacements and head loss characteristics. The drive gives a stepless speed range from 6 to 200 r.p.m. to the faceplate.

A small ball pump driven from the faceplate gear ring supplies pressure fluid to a hydraulic motor of similar construction fitted on the feed mechanism of the machine. This separate hydrostatic feed drive gives a stepless cutting speed range from 0·002in to 0·2in per revolution and is thus tied to the rotation of the table, although its rate can be varied at will independently of the table speed. A shaft driven from the toolbox feed shaft carries cams that are moved axially as the tool is moved across the work. These cams are connected to the controls of the table motors and main pump to vary their displacements automatically during machining and with this control there is provided a constant cutting speed for changing diameter.

The characteristics demonstrated make hydrostatic transmission applicable, with appropriate modification, to many machine tools where a wide range of stepless speeds with constant cutting feeds for changing diameter is desirable. It is of simpler construction and more compact than complicated systems of gearing or electronic controls, and eliminates any need for gear changing whilst a cut is in progress. Furthermore the use of a hydraulic drive tends to ease shocks on a cutting tool during intermittent machining operations.

With these points in mind and knowing that an opportunity was given at the International Machine Tool Exhibition to see the possibilities of the system we approached a number of machine tool builders and makers of hydraulic drives for their comments.

Impact Extrusion of Steel

Although the technique of impact extrusion for the production of steel components has already been applied fairly extensively in

Fig. 1—Vertical boring mill equipped with N.E.L. hydrostatic drive

* Previous articles in this series are :

No. I.—National Engineering Laboratory: " Some Engineering Advances," April 29, 1960.

No. II.—Water Pollution Research Laboratory : " Pollution from Electroplating Wastes and from Oil," November 25, 1960.

Germany and the U.S.A., its use in Britain is still in the early stages. In general it might be said that the same basic principles apply for steel as in the impact extrusion of non-ferrous metals, but each individual case calls for a study of slug preparation, tool design and the pressures to be used. The process offers a high production rate, a product of accurate dimensions with a good surface finish, and improved mechanical properties as a result of cold working ; in addition, the use of cold extrusion in place of machining gives a very substantial saving in material.

The section of the laboratory concerned with research on metal-forming processes works in close co-operation with manufacturers and users of extruded steel components and press equipment makers. Sponsored investigations on particular eold-extruded products have been carried out in addition to the general basic investigations of extrusion processes.

In the summary to the report by McKenzie and Rodger it is stated that the cold extrusion of various steels under impact conditions was investigated and the influence of various extrusion factors on the extrusion-pressure/punch-stroke characteristic, work done, process efficiency, metal flow and product properties was determined.

The study of the effect of factors such as type of product, die geometry, punch impact speed, lubrication, slug condition and shape was confined to the extrusion of a 0·15 per cent carbon mild steel. In the study of the effect of reduction, a range of steels with carbon contents up to 1 per cent and alloy steels such as En 33 (3 per cent nickel), En 40B (3 per cent chromium) and En 58B (18/8 austenitic) was extruded. From consideration of tool stress the extrusion ratios were limited so that a maximum extrusion pressure of 180 tons per square inch was not exceeded. A few tubes were extruded at pressures over 200 tons per square inch without tool failure.

A linear relationship between maximum extrusion pressure and the logarithm of the extrusion ratio satisfied the experimental results above an extrusion ratio of 1·8. The pressures on the die face, in the extrusion of rod and tube, and on the punch face, in the extrusion of can, were shown to have a minimum value at, or near, an extrusion ratio of 2. The extrusion characteristic, maximum pressure, metal flow, product hardness and dimensional accuracy were found to be dependent on the entry profile of the die.

FIRM'S COMMENTS

Upon approaching firms for comments we discovered that our choice of subject was less suitable for the purpose of this series of articles than we had supposed. The fact is that development has been carried so far by the Laboratory that a number of firms are considering applications. Under the circumstances, with one exception, none of the machine tool makers we approached would comment upon the hydrostatic drive as developed by N.E.L. The impression we gained was not that interest was lacking but quite the reverse—that, in fact, any comment at all might give information away. This attitude can be explained by the unwillingness of firms engaged in a competitive industry to give any indication of their new developments to other manufacturers. From the angle of the machine tool industry, therefore, the degree to which the hydrostatic drive will be adapted can only be a matter of conjecture. But it certainly shows promise and we feel little doubt that in the not too distant future hydrostatic drives will form the basis of some interesting new developments in machine tools as well as in many other forms of equipment.

H. W. Kearns and Co., Ltd.

We are informed by H. W. Kearns and Co., Ltd., of Broadheath, near Manchester, that it considered N.E.L. was right in directing its attention to machine tool drives and that such development was a step in ensuring that no channel likely to increase the efficiency of machine tools would be left unexplored. Whilst agreeing that the hydrostatic drive using the ball pump might well be applied to some of its machines the firm was not, however, prepared to investigate its possible adoption until more was known of the efficiency which could be expected of the drive under actual workshop conditions. At present the gear drives as used on Kearns boring machines were giving the required performances and until the efficiency, active life and relative economies of the proposed hydrostatic drive could be shown to be a decided improvement on the conventional equipment, the company was not offering this on its machines. Should, however, any customer express an interest in the hydrostatic drive and wish to have it incorporated on a new Kearns machine the company would be quite prepared to co-operate in every way and investigate the possibilities to suit the particular application.

Armstrong Whitworth (Metal Industries), Ltd.

The pumps and motors for the boring mill rebuilt to the designs of N.E.L. were made by Armstrong Whitworth (Metal Industries), Ltd., Gateshead upon Tyne. This company, which is to manufacture ball pumps for industrial applications, stated that in all its dealings with N.E.L. during the design and manufacturing stages of the prototype transmission were satisfactory and that it would not hesitate to make use of the Laboratory facilities should the occasion arise. When it embarked upon the detailed design work for making the prototype equipment the firm was given the basic research data from original work carried out at N.E.L. and in preparing the manufacturing drawings it received the fullest co-operation from the Laboratory staff.

Dowty Hydraulic Units, Ltd.

Two manufacturers of hydraulic equipment pointed out that they were already making hydrostatic drives and that they were, therefore, not at present interested in one incorporating the ball pump. The comments of Dowty Hydraulic Units, Ltd., were of interest as they took in further points in connection with the activities of N.E.L.

This firm pointed out that, whilst the hydrostatic drive for machine tools developed by N.E.L. was interesting, the company was already manufacturing—as a standard product used on other plant—a hydrostatic drive which was readily adaptable for large machine tools such as planers. Furthermore, the relatively restricted number of hydrostatic drives required for machine tools would not justify economically the firm embarking upon a programme of tooling up and manufacturing a new line of the smaller capacity units envisaged by N.E.L. unless a wider field of application gave promise. Nevertheless, the company fully appreciated the value of the work which N.E.L. had done in setting up high quality equipment for calibrating the performance of hydrostatic drives. Dowty Hydraulic Units and other firms making this type of drive were making good use of these facilities at N.E.L.; consequently a standard was being established for the comparison of drive performance.

Another instance of the use made of N.E.L. had been in the development of a special reservoir for hydrostatic drives. It is important that the fluid in such a drive should be as free as possible of suspended air, as this affects compressibility. Ideally, the reservoir of a transmission would be large to allow the air to settle out. Unfortunately, this is not possible in every case

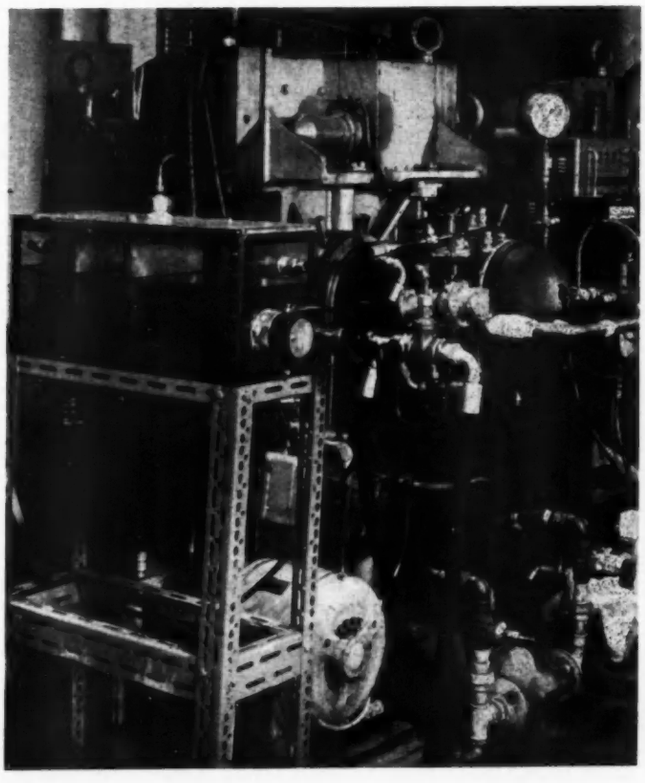


Fig. 2—Experimental reservoir for hydrostatic drives

and when small reservoirs are needed because of space limitations it is essential that they should be equipped with every means of causing the returning oil to release its air. Mr. Firth's paper "An Old and New Look at Oil Hydraulics" (*Compressed Air*, October, November and December, 1958) gave useful clues to the design of such a tank.†

The firm made a "Perspex" reservoir of 5 gallons capacity, i.e. about one-third of the tank volume it would normally specify, to try out N.E.L. ideas. This experimental unit is shown on its stand in the left-hand section of Fig. 2; the photograph was taken during tests at East Kilbride on a complete "Dowmatic" drive. The general recommendations of N.E.L. were confirmed. For example, the diffuser on the return side was the most important means of ridding the returning oil of air. Vertical grills also helped to "strain" air bubbles from the oil as it passed through the tank. A suction strainer on the other hand caused air to be released inside it, causing air to coagulate into large bubbles which were sucked down into the inlet pipe to the boost pump. However, it was found that the diffuser should be made of gauze rather than perforated sheet, which meant that the diffuser would be somewhat larger than Mr. Firth's recommendations in order to cut down headloss across it. Likewise, the vertical grills too behaved better when made of gauze of about 60 mesh. Incidentally, the fluid used was of the S.A.E.10 viscosity classification.

On the broader issues, the company hoped that N.E.L. would extend the use of its excellent facilities into research on the many fundamental problems that remain to be solved in fluid power control. Typical subjects on which it considered much more fundamental knowledge was needed are: face-type rotary seals; relief valve stability; hydraulic fluids—effects of pressure-viscosity characteristics, and shear stability of V.I.-improved oils, for example; hydrostatic balancing of pump components such as piston slippers and valve faces; and fundamentals of sealing with resilient materials.

Although a certain amount of such research was being done both by firms and by the British Hydromechanics Research Association, it was restricted by economic considerations. Most of the firms making oil hydraulic apparatus for mobile use, machine tools and mechanical handling equipment, were relatively small establishments; and it was obviously an overall waste of resources for the same basic problems to be probed by a number of independent concerns. It would be more efficient if the resources of industry were to be used in applied research, while N.E.L. helped to provide the fundamental information. N.E.L. Fluids Note No. 53 on "The Design of Relief Valves for Oil Hydraulic Circuits" seemed to promise that this approach was on the way. Unfortunately, these hopes had not been borne out in this instance, for there had been a stony silence since the Note was issued in November 1957.

Scottish Machine Tool Corporation, Ltd.

Some of the firms which were asked if N.E.L. reports or facilities were used in connection with their problems in the impact extrusion of steel declined to comment. One firm said quite frankly that so much had been written on the process it did not wish to add on the verbiage on the subject.

The Scottish Machine Tool Corporation, Ltd., stated without hesitation that as manufacturers of extrusion presses it found the research work carried out at N.E.L., East Kilbride, of immense value both theoretically and practically. It added that with respect to the various reports which had been issued by N.E.L., it must surely be true to say that they have been among the few published reports on the subject of extrusion which have given all the facts simply and clearly, and have been compiled in such a manner as to make it possible for the problems applicable to extrusion work to be calculated without undue difficulty.

This company had worked in the past, and would continue to work in the future, very closely with N.E.L. on specific problems appertaining to the manufacture of certain steel extruded components for use in various sections of industry. There was, in its opinion, positively no doubt as to the value of the N.E.L. research work and it hoped that in the future more industrial support would be given to the establishment in order that it might continue with investigations into some of the more complex problems of extrusion such as the determining of tool life, automatic feeding for long production runs, lubrication breakdown, temperature measurement and other problems connected with tooling and long production runs.

In addition this firm would like to see research work carried out on the extrusion of high carbon and chrome steels, &c. It felt it was, however, unfortunate that in this country, where there is rather a dearth of industrial research, there are two organisations both of which are investigating the problems of cold extrusion as part of their research programmes, viz. N.E.L. and P.E.R.A. In the firm's opinion it would be more advantageous to industry if all the sponsored investigations on extrusion were made by N.E.L., since it had far greater experience on the subject, and the reports which P.E.R.A. made available to non-members were of much less value. Extrusion was a new method of production which could change the face of industry in this country provided adequate support is given to research into the practical use of the process and N.E.L. was capable of carrying out this work.

British Motor Corporation

The motor car industry is one which, probably more than any other in the country at the present time, is interested in the cold forming of components and we asked Mr. F. Griffiths, the chief production development engineer of the British Motor Corporation, Ltd., for his comments on the work of N.E.L.

The work carried out by the corporation in developing cold forming techniques for steel components was described in some detail in a paper‡ presented at the conference on the cold extrusion of steel last year by Mr. F. Griffiths. The corporation, with its future manufacturing capacity of about 1,000,000 vehicles a year, is naturally very interested in techniques and processes designed to reduce the wastages in materials and capital equipment involved in conventional machining practice. In a concern such as this the reduction, or even more desirable still, elimination, of machining of steel components from the bar or rough forgings could well lead to the annual saving of millions of pounds. As a result of investigations and development work over the past four or five years Mr. Griffiths has established that cold formed steel components can now be produced more economically than hot forgings and to tolerances which largely eliminate subsequent metal-removing machining operations.

Mr. Griffiths informed us that at no stage in the development of the cold flow forming techniques and tooling used by his company had reports on work carried out at N.E.L. or any other research establishment been found of practical use. He expressed his appreciation for the willing co-operation and assistance that was obtained from Mr. Morgan and Mr. Kitchen of the Birtley Ordnance Factory, from whom down-to-earth practical cold flow forming techniques were obtained. He also indicated that some good practical information on shop floor work was obtained from Liebergeld of Nürnberg, Germany. He considered that fundamental research on the cold forming of steel had to date introduced a degree of confusion and complication into what had been found to be a relatively straightforward process of manipulation and that the problems were by no means so complicated as research establishments had indicated. Economic success had been achieved not by the use of complicated theory but by the development of a suitable hydraulic press and tooling designed on practical lines to ensure the correct flow of metal from pellets or preformed billets progressively in one or more operations. Mr. Griffiths indicated that the actual process of cold forming was not now a problem—the real problem existed in the cost of the capital equipment required and its amortisation.

Discussing the broader field of fundamental research into machine tools and machining, Mr. Griffiths considered that the considerable amount of time and capacity used in this connection might well be devoted to the individual basic problems of production to give the increased output at the correct economic cost which is essential to the well-being of industry. Much of the fundamental research work in progress provided interesting academic exercises which industry was not likely to find of value. At the present time techniques were changing at such a rate that it was doubtful if the theories evolved by fundamental research would ever catch up, and there was evidence that many of the techniques upon which research workers were occupied might well be discarded in production establishments before tangible results were achieved.

Technical Reports

Sea Defence Groynes. By A. C. Oliver and H. Richardson. The Timber Development Association, Ltd., 21, College Hill, London, E.C.4. Price 3s. 6d.—A general review of sea defence in this country covering legislation, geology, &c., is given. Present ideas on the causes of movement of beach material and the particular effect of sea defence groynes in stabilising the foreshore are then described. Quantities and species of timber used in groyne construction, and a detailed survey of the types of groyne construction used on the south and east coasts are given.

Water Metering and Water Meters. (N.E.L. Fluids Report No. 94.) By S. P. Hutton. National Engineering Laboratory, East Kilbride, Glasgow. No price quoted.—This publication comprises a general report prepared for the Fifth International Water Supply Congress; it summarises the results of surveys made by national rapporteurs in eighteen countries. Its main objects are: (*a*) to review the present state of water metering; (*b*) to examine the limitations of current practice; (*c*) to describe new developments; (*d*) to discuss trends and to consider future requirements. It covers pressure difference and mechanical types of meter for measuring water flow in pipelines. Because of growing demands for water, rising costs and shortage of suitable water sources, there is a strong economic pressure to conserve water and to distribute it as economically as possible. Such factors have increased the need for water meters of improved accuracy and reliability. Methods of achieving optimum efficiency and economy in distribution are described, and the possibilities for future improvements reviewed.

† See the first article of this series (April 29, 1960, page 712) where the tank is illustrated.

‡ Organised by the Institute of Sheet Metal Engineering and held at Sheffield, November, 1960.

Amphibious Cargo Carrier

By R. M. OGORKIEWICZ, M.Sc.(Eng.), A.M.I.Mech.E.

Details have now been released of a new wheeled cargo carrier developed by Alvis, Ltd., to meet a long-standing military need for cross-country transport vehicles. The following article describes the principal features of this vehicle and some of the implications of its development.

MILITARY requirements for transport vehicles have been answered, generally, by the provision of commercial trucks, modified to a greater or lesser extent for military use. Recourse to such adaptations has obvious economic advantages, but it has failed to provide vehicles as good as they might be from the point of view of military operations. In particular, adaptations of commercial vehicles fall short of optimum performance off the road, which is inevitable since these vehicles are originally designed for use on roads and not for the cross-country movement so often necessary in military operations. In consequence, armies still lack transport vehicles really suited to their needs and they are particularly deficient in tactical cargo carriers. Without such vehicles, whose performance would match that of the fighting vehicles and which could operate effectively right up to the forward areas, fighting units can not be provided efficiently with the necessary logistical support and their effectiveness suffers. There is, therefore, a very strong operational incentive for the development of special cross-country military transport vehicles and several experimental models have, in fact, appeared abroad during the past few years. In view of this, it is all the more interesting that a cross-country cargo carrier has now also been developed in this country, by Alvis, Ltd. This vehicle, the Alvis "Stalwart," began as a private venture but the manufacturer's initiative has now been rewarded by a War Office order for a number of vehicles for troop trials.

The "Stalwart" is a logical development of the F.V.600 series of six-wheeled armoured vehicles produced for some eight years by Alvis, Ltd., and its chassis is essentially the same as that of the earlier F.V.603 "Saracen" armoured personnel carrier and the F.V.601 "Saladin" armoured car. As in the case of the "Salamander" fire crash tender (F.V.651) the lower part of the "Stalwart" hull is fabricated out of mild steel to conform to the shape of the lower portion of the F.V.600 hull, but the superstructure is peculiar to the vehicle, having a forward control cab and a cargo compartment with drop sides and tail, which is capable of accommodating a normal payload of 5 tons. Moreover, the hull, cab and cargo compartment are fully sealed for flotation and the vehicle is fitted with two Saro/Gill propulsion units for water operation.

The F.V.600 series chassis, on which the "Stalwart" is based, has six independently sprung driven wheels. The suspension is of the parallel double transverse wishbone type and provides for 5in bump and 5in rebound movement. Springing is by torsion bars and there are two hydraulic telescopic dampers at each front and rear wheel and one at the centre wheels, each wheel also having two suspension limit stops of the enclosed rubber buffer type externally similar to the dampers. Both front and centre wheels are steered, steering being by positive mechanical linkage with hydraulic assistance, but the centre wheels have only half the angular deflection of the front wheels, this being arranged by means of a rocking beam with a two to one leverage which transmits movement from the front to the centre wheels on each side of the vehicle. Transmission layout is of the type successfully established by Daimler scout and armoured cars during the 1939–45 war, and embodies a single central differential from which the drive is transmitted to shafts and bevel boxes along each side of the hull. This layout makes it possible to locate the engine and the driver between the drive shafts and thereby lower the centre of gravity and reduce the silhouette of the vehicle, which is particularly important in the case of the "Saladin" armoured car, but less so in the case of the "Stalwart." On the other hand, the single central differential is an advantage to all vehicles of the family, as it eliminates the possibility of cross-spin and improves off-the-road performance. To improve the latter still further in the "Stalwart," the standard four-star differential has been replaced by a "No Slip" differential.

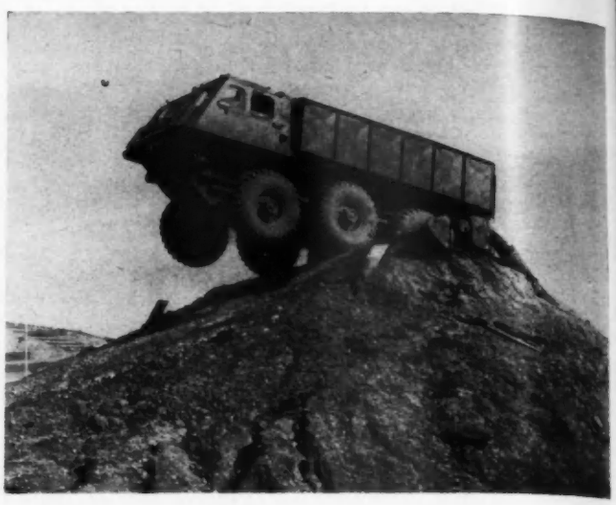
As on the other models, the differential is embodied in a transfer box with forward and reverse change: the drive from the bevel box at each wheel station is taken by shafts with splined sleeves and Girling-Tracta constant velocity joints at the inboard and outboard ends to two-stage epicyclic hub reduction gears. However, in the present version of the "Stalwart," the normal five-speed preselective epicyclic transmission with a fluid coupling has been replaced by a dry twin-plate 12in clutch and five-speed synchromesh gearbox with servo-assistance and a power take-off. The transmission alteration has been done mainly in the interest of towing ability, which is considered particularly important, to enable one carrier to tow another if the latter breaks down in the field and thus ensure the delivery of its cargo of ammunition or fuel. As a result of the change, the overall top gear ratio is 11·67 and the bottom gear 89·65. Brakes are also different from the F.V.600 series, Dunlop hydraulic caliper disc brakes with air pressure boost being used on all six wheels. As an alternative, Lockheed caliper brakes may also be used and Girling totally enclosed disc brakes are also under consideration.

The power unit is a Rolls-Royce B.81/80B, 220 b.h.p. eight cylinder gasoline engine located at the rear, below the floor of the cargo compartment. The radiator is mounted behind the engine and cooling air is drawn from the rear of the cab and exhausted at the rear of the vehicle. The dry-sump engine is similar to those used in earlier models of the family, but it could be replaced by a K.60 multi-fuel engine on future models, the Rolls-Royce B and K series engines being interchangeable.

Tyres are of the same size as on the fire crash tender, that is 14·00-20, in contrast to 11·00-20 tyres on the "Saracen" and 12·00-20 tyres on the "Saladin," and, unlike the last two, they are not of the bullet-proof run-flat type, which affords greater latitude with regard to the inflation and ground pressure. Adjustment of inflation pressure to suit terrain condition is particularly important in this type of cross-country vehicle but its design has not gone so far as to provide means of controlling tyre pressure on the move from the driver's seat, as was done on the G.M.C. DUKW 6×6 2½-ton amphibious truck used extensively during and since the 1939–45 war and now also on the Soviet BTR-152 6×6 armoured personnel carriers.

Like other multi-wheeled vehicles, the "Stalwart" could have propelled itself in water by means of its wheels at up to about 3 m.p.h., but this speed is not considered adequate for crossing rivers. In consequence, it has been provided with two Saro/Gill propulsion units, one in each side of the hull at the approximate centre line of the rear wheel station. The propulsion units are mechanically driven from the power take-off and the outlet of each incorporates a rotating cascade, which in conjunction with the road wheels steers the vehicle in water, wheels alone being able to provide only limited water steering. Towing tank tests with models at Saunders Roe have indicated that the "Stalwart" is capable of a water speed in excess of 5 knots and it is said to have been operated at about 4 knots. The latter is comparable to the water speed of some American amphibious vehicles but although the water trials have been encouraging it is worth noting that recent American designs have aimed at, and in several cases achieved, water speeds in excess of 6 m.p.h., which is

Alvis "Stalwart" P.V.2 prototype swimming off shore with the trim vane in front of the cab hinged forward



Because of the close spacing of the wheels, the "Stalwart" can negotiate obstacles which would defeat standard military trucks

considered desirable for the crossing of the faster flowing rivers.

In addition to the two propulsion units and the water sealing of the hull, cab and cargo compartment, the "Stalwart" is also fitted with two hydraulically driven bilge pumps, each with a capacity of 60 gallons per minute, and a trim vane hinged at the front of the cab. The latter follows the practice adopted by the Food Machinery and Chemical Corporation on the M59 Armoured Infantry Vehicle built in 1953 and since used on other American vehicles, but the vane is in two pieces so that it can be folded below the cab windscreen when not in use. All these features should make the "Stalwart" well capable of crossing inland waters and, under suitable conditions, it is also capable of swimming ashore from landing craft. However, it must be emphasised that in common with the M59 and other vehicles capable of crossing inland waters, it is neither able nor intended to compete with amphibious vehicles designed specifically for landing from the open seas and capable of negotiating heavy surf, such as the tracked landing vehicles, or LVT's, developed for the U.S. Marine Corps.

Swimming ability is now a common requirement for the lighter armoured fighting vehicles and it is, therefore, appropriate that the "Stalwart" also should possess it. This does, unfortunately, impose its penalties, notably that of a high silhouttee resulting from the bulk necessary for buoyancy. However, with an overall height of 8ft 1in, or 7ft 9in with the commander's cab hatch removed, the "Stalwart" is no worse than other comparable vehicles and its dimensions are sufficiently modest to allow it being carried by such tactical transport aircraft as the A.W.660. The height of the cargo compartment floor, which is almost 5ft off the ground, may also be excessive for loading under some conditions but it is very convenient for off loading ammunition and fuel on to the engine deck of tanks such as the "Centurion." Moreover, the fact that the engine and other heavy mechanical components are all below the cargo compartment means that the centre of gravity of the vehicle is low and well below the metacentre, which makes it very stable when floating.

In its present form the cab does not conform to any service specification and may well be redesigned after the troop trails. As it is, it provides ample room for three men, or two men and wireless equipment, and entry is only by a roof hatch. Our illustrations show that not only the side but also the forward-facing small glasses drop for ventilation. An obvious possibility is the provision of some degree of armour protection, particularly for the driver. This would be highly desirable from the point of view of the freedom of operation in forward areas but the protection would inevitably reduce the payload and, judging by the American development of armoured and unarmoured versions of tactical cargo carriers, there is yet no agreement on this point.

The "Stalwart" is rated at a payload of 5 tons, which is very attractive for a cross-country cargo carrier, if still a little disappointing in relation to the total weight of 13·3 tons, laden. It means that the payload represents considerably less than half of the total vehicle weight, which has been achieved with a number of recent American cross-country vehicles. By comparison with some of the American multi-wheeled cargo trucks, the payload also seems somewhat optimistic for cross-country operation, particularly in muddy terrain. For instance, the 8×8 XM-410, which has 14·00-18 tyres, is only rated at 2½ short tons and so is the 8×8 XM-521, which has 7·50-20 tyres, and in both cases the net weight is less. Admittedly, the "Stalwart" has larger tyres than either of the above two trucks, but it has two fewer and their overall diameter is not significantly greater—and performance in cohesive soil is principally a function of the number of wheels and outside tyre diameter. The "Stalwart" is said to have been tested successfully in the bogging pit at the Military Engineering Experimental Establishment, but otherwise most of its cross country trials appear to have been performed at the Royal Armoured Corps Centre, at Bovington Camp in Dorset, in fairly sandy soil which presents less of a problem to wheeled vehicles than more cohesive soils.

There is, however, no doubt about the potential utility of the "Stalwart" as a versatile cargo carrier. It is undoubtedly superior to the general service type of truck based on commercial designs in off-the-road operation and to tracked cargo carriers when operation on roads and hard surfaces is involved. The latter are, nevertheless, highly competitive, particularly if fitted with the rubber bushed and rubber padded type of track, which has been neglected far too long in this country. It is perhaps not generally appreciated that with this type of track used in vehicles of the "Stalwart's" weight, track life now exceeds 4000 miles and can reach 9000 miles. By comparison, the tyre life on the "Stalwart" is expected to average about 8000 miles.

Otherwise, the "Stalwart" is superior to any tracked competitor in higher road speed, in causing less damage to road surfaces, and in being less noisy, which is important for tactical moves and reduces crew fatigue, while in such other respects as the 5ft 9in trench crossing ability it is comparable with tracked vehicles of similar dimensions. Its maximum road speed is actually 45 m.p.h. and its range of action 450 miles, on roads, with a 100 gallon tank capacity.

In general, the "Stalwart" is a logical extension of the existing family of vehicles produced by Alvis, Ltd., and used in numbers by British and other forces. For them its adoption would, therefore, considerably simplify training and maintenance but it is understood that interest has also been shown by others, including the United States and Swedish Armies. It has also attracted the attention of civilian organisations, being suitable, for instance, for oil and timber companies. It is obviously capable of further development and adaptation for special purposes, such as those of missile launcher, recovery vehicle or bridge-layer.

All the details quoted in this article apply to the second, recently completed P.V.2 prototype. The original P.V.1 model has been running for over a year and some photographs of it appeared in the Press earlier this year. It differs in several respects, including the superstructure and mechanical components, and it is not capable of swimming, but it has provided useful experience in land operation.

1960 Road Census Results

In the fifth of a series of annual checks made by the Ministry of Transport since 1956 to provide estimates of vehicle mileage on trunk and class I roads and to enable traffic trends over these roads to be measured, counts were taken at a hundred points from 6 a.m. to 10 p.m. each day during the week ended August 21, 1960.

It was estimated that, during the week, some 835 million vehicle miles were travelled by all types of vehicles. Of this total, about 48 per cent was travel on urban roads, while 43 per cent of the total (363 million vehicle miles) was on the trunk roads, though they comprise only 30 per cent of the total mileage.

A similar census was taken at thirty-two points in Scotland by the Scottish Home Department in the same week. From this, it was established that 113 million vehicle miles were travelled on trunk and class I roads in Scotland during the week.

The total estimated vehicle mileage on trunk and class I roads in Great Britain was thus 948 millions.

THE ENGINEER

TECHNICAL CONTRIBUTORS SECTION

AUGUST, 1961

Stability Criterion for Oil Whip of a Rotor in Journal Bearings

By FINN ORBECK, B.Sc., A.R.C.S.T., Ph.D.

With few exceptions, earlier works on the stability against half-frequency whirl or oil-whip of rotors supported by journal bearings consider the rotor and its oil film support as a two-dimensional mass-spring vibrational system. Proceeding from this point of view stability criteria are derived. It is shown by experiment,[1] however, that the frequency response curve for oil-whip for horizontal rotors is distinctly different from that of a mass-spring vibrational system in that the former shows no amplitude up to a certain speed, then a sharp onset of amplitude, followed by a gradual increase with speed thereafter. The mass-spring vibrational system, however, has a typical resonance peak in its frequency response curve with decreasing amplitude for speeds above and below the resonance speed. The author has given an analytical explanation for oil-whip for vertical rotors leading to a frequency response curve comparable with that obtained by experiment in an earlier paper.[2] This article endeavours to explain the sharp onset of oil-whip at a certain critical speed for horizontal rotors and gives a method for calculating this critical speed.

Theory

A THEORETICAL treatment for the oil-whip of vertical rotors supported by plain journal bearings was given by the author in an earlier publication.[2] From the conditions of equilibrium of the forces due to the oil pressure and the viscous drag as well as the centrifugal force it was possible to obtain an analytical description of the problem and, finally, solve to obtain the frequency response. The treatment was restricted to vertical rotors. This article endeavours to derive a stability criterion against oil-whip for a rotor supported by journal bearings when the rotor is subjected to a constant side thrust.

Fig. 1 shows a diagram of the forces acting on a journal which performs oil-whip. It will be seen that the force due to viscous drag is balanced by the tangential component of the force due to the oil pressure. The radial component of this latter force serves to balance the centrifugal force. If the centre of the journal moves in a circular path about the centre of the shell, the forces of Fig. 1 will remain constant over the path since they are all independent of angular position. The force system, however, is dependent on the eccentricity and will therefore vary over the revolution if the journal is disturbed from its circular path motion. A complete solution for this latter case is accordingly more difficult to obtain.

The stability criterion of the journal does not depend on the path of the journal when it has become unstable. It is therefore sufficient to consider the position of the journal at the last moment when it is stable and the stability criterion will be determined by its eccentricity in this position. Thus, the stability criterion can be determined for any rotor which is subjected to a constant side thrust.

Let us consider a journal of mass M. The centre of the journal is assumed to be at rest at an arbitrary distance from the centre of the shell. This journal will remain stable as long as the rate of increase of the centrifugal force in oil-whip with eccentricity is less than, or equal to, the rate of increase of the radial component of the oil pressure force which would be caused by oil-whip. This criterion can be expressed by the following relation :

$$\frac{d}{de}\left(M\omega_1^2 e\right) \leq \frac{d}{de}\left(P\cos\alpha\right) \quad . \quad . \quad . \quad (1)$$

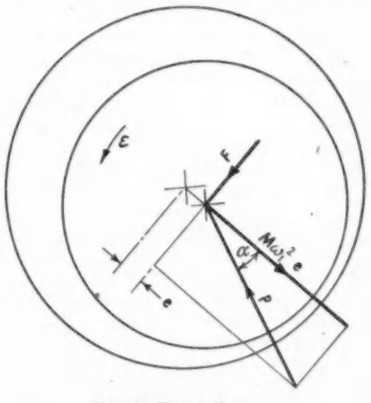


Fig. 1—Force diagram

The frequency of whirl ω_1 is a function of the frequency ω and the eccentricity ratio as shown by reference 2, equation (29). This equation may be restated as follows :

$$\omega_1 = \frac{\omega}{2}\left\{1 - \frac{\dfrac{2\pi^2}{\varepsilon}\left(\dfrac{1}{(1-\varepsilon^2)^{\frac{1}{2}}} - 1\right)}{\left(\dfrac{D}{C_D}\right)\left(\dfrac{L}{D}\right)^{1\cdot73}\left(\dfrac{1}{C_n}\right)\sin\alpha}\right\} \quad . \quad (2)$$

The force component $P\cos\alpha$ is given by the following relation which is also quoted from Reference 2, Equation (11) :

$$P\cos\alpha = \mu(\omega - 2\omega_1)LD\left(\frac{D}{C_D}\right)^2\left(\frac{L}{D}\right)^{1\cdot73}\frac{\left(\dfrac{1}{C_n}\right)\cos\alpha}{2\pi} \quad . \quad . \quad . \quad . \quad (3)$$

Making use of Equations (2) and (3) the stability criterion may be rewritten as follows :

$$\frac{d}{de}\left\{\frac{M\omega^2}{4}\left(1 - \frac{2\pi^2}{\left(\dfrac{D}{C_D}\right)\left(\dfrac{L}{D}\right)^{1\cdot73}}\left\{\frac{\dfrac{1}{(1-\varepsilon^2)^{\frac{1}{2}}} - 1}{\varepsilon\left(\dfrac{1}{C_n}\right)\sin\alpha}\right\}\right)^2 e\right\} \leq$$

$$\frac{d}{de}\left\{\mu(\omega - 2\omega_1)LD\left(\frac{D}{C_D}\right)^2\left(\frac{L}{D}\right)^{1\cdot73}\frac{\left(\dfrac{1}{C_n}\right)\cos\alpha}{2\pi}\right\} \quad . \quad . \quad . \quad . \quad (4)$$

The second term on the left-hand side of the above equation is small compared to one and its square may therefore be neglected. Equation (4) can thus be rearranged to give the following expression :

Nomenclature :

- ω—Frequency of rotation (1/sec)
- ω_1—Frequency of whirl (1/sec).
- e—Eccentricity (in).
- ε—Eccentricity ratio.
- P—Force due to oil film pressure (lb).
- α—Attitude angle.
- M—Rotor mass (lb sec²/in).
- D—Diameter of bearing (in).
- C_D—Diametral clearance (in).
- L—Length of bearing (in).
- $1/c_n$—Load number of bearing.
- μ—Viscosity of lubricating oil (lb sec/in²).
- P'—Force/projected area for bearing (lb/in²).

Technical Contributors Section *(continued)*

$$M\omega\left(1-\frac{4\pi^2}{\left(\frac{D}{C_D}\right)\left(\frac{L}{D}\right)^{1\cdot73}}\frac{d}{d\varepsilon}\left\{\frac{\frac{1}{(1-\varepsilon^2)^{\frac{1}{2}}}-1}{\left(\frac{1}{C_n}\right)\sin\alpha}\right\}\right)\leq$$

$$8\pi\mu L\left(\frac{D}{C_D}\right)^2\frac{d}{d\varepsilon}\left\{\frac{1}{\varepsilon}\left(\frac{1}{(1-\varepsilon^2)^{\frac{1}{2}}}-1\right)\cot\alpha\right\} \quad . \; . \; (5)$$

Let us introduce the following notations :

$$f(\varepsilon)=\frac{d}{d\varepsilon}\left\{\frac{1}{\varepsilon}\left(\frac{1}{(1-\varepsilon^2)^{\frac{1}{2}}}-1\right)\cot\alpha\right\} \quad . \; . \; . \; . \; (6)$$

$$g(\varepsilon)=\frac{d}{d\varepsilon}\left\{\frac{\frac{1}{(1-\varepsilon^2)^{\frac{1}{2}}}-1}{\left(\frac{1}{C_n}\right)\sin\alpha}\right\} \quad . \; . \; . \; (7)$$

The stability criterion will then take the following form :

$$\omega\leq\frac{8\pi\mu L\left(\frac{D}{C_D}\right)^2 f(\varepsilon)}{M\left(1-\frac{4\pi^2}{\left(\frac{D}{C_D}\right)\left(\frac{L}{D}\right)^{1\cdot73}g(\varepsilon)}\right)} \quad . \; . \; (8)$$

When the constant load characteristics of the bearing are known the functions $f(\epsilon)$ and $g(\epsilon)$ can be calculated from Equations (6) and (7). For the purpose of further work in this article, the experimental constant load characteristics for a bearing of length to diameter ratio equal to one-half has been selected after Kreisle.[3] These characteristics give values for the functions $f(\epsilon)$ and $g(\epsilon)$ as shown by the Table :—

ε	α deg.	$\frac{1}{C_n}$	$f(\varepsilon)$	$g(\varepsilon)$
0·05	85·5	0·26	0·079	0·080
0·1	81	0·63	0·154	0·060
0·15	77	1·05	0·208	0·046
0·2	74	1·65	0·299	0·051
0·3	67	2·86	0·540	0·049
0·4	59	4·75	0·872	0·037
0·5	52	7·7	1·48	0·039
0·6	44	12·2	2·58	0·043
0·7	37	19·5	5·06	0·033
0·8	30	37		

Example : The following example will now be carried out to demonstrate the calculations which are necessary to find the stability limit for any particular installation. Let us assume the following dimensions : The rotor is horizontal and weighs 3 tons, $L=6$in, $D/C_D=1000$, $L/D=\frac{1}{2}$, $\mu=5\times10^{-6}$ lb sec/in^2.

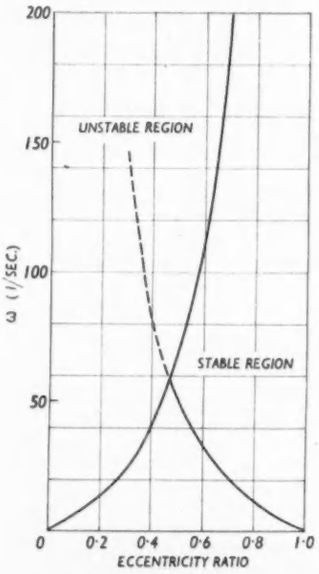


Fig. 2—Stability limit

The limit of stability as calculated from Equation (8) by making use of the above data is shown by Fig. 2.

The load number will be given by the following equation :

$$\frac{1}{C_n}=\frac{2\pi p'}{\mu\omega}\left(\frac{C_D}{D}\right)^2\left(\frac{D}{L}\right)^{1\cdot73} \quad . \; . \; (9)$$

Since the journal is loaded by its own weight, the average pressure on the bearing will be given as follows :

$$p'=3\times2240/6\times12=93\cdot3\text{ lb/in}^2$$

Hence $1/c_n=389/\omega$

With the above value of the load number the curve of eccentricity ratio versus load number for the bearing can be replotted as a curve of speed of rotation versus eccentricity ratio as shown partly dotted in Fig. 2. As the rotor gains speed, its eccentricity ratio will alter according to this curve and, at the point where this curve crosses the stability limit, oil-whip will start.

The above theory explains the sharp onset of oil-whip observed for a horizontal rotor by Newkirk.[1]

REFERENCES

[1] Newkirk, B. L., *Transactions A.S.M.E.*, July, 1956, page 985.
[2] Orbeck, F., *Transactions A.S.M.E.*, October, 1958, page 1497.
[3] Kreisle, L. F., *Transactions A.S.M.E.*, July, 1956, page 955.

Complex Stress Creep Fracture of Copper at 250° under Vibratory Stress

By A. E. JOHNSON, D.Sc., M.Sc.Tech., M.I.Mech.E.,* J. HENDERSON, B.Sc.,* and B. KHAN, B.Sc.

The purpose of this investigation was to determine the effect of vibratory stress on the fracture under complex stress creep conditions of commercially pure copper at 250 deg. Cent. A number of tests to fracture, under conditions of pure complex stress creep, pure complex stress fatigue and combined complex stress creep, and complex stress fatigue, have been made on specimens of commercially pure copper at 250 deg. Cent., and the results analysed. This article deals purely with an investigation of the effect of vibratory stress on the criterion of complex stress creep fracture, and is not in any sense intended as a comprehensive investigation of the complex stress fatigue properties of the material at high temperatures.

AN investigation of the complex stress creep fracture characteristics of a number of metallic alloys, at their appropriate normal working temperatures, has been in progress for a number of years at NEL, and the results of this investigation have been published, or are currently in course of publication.[1, 2] Metallic alloys or metals examined have comprised a 0·5 per cent molybdenum, 0·17 per cent carbon steel at 550 deg. Cent. commercially pure copper at 250 deg. Cent., RR 59 aluminium alloy at 200 deg. Cent., a 0·2 per cent carbon steel at 450 deg. Cent., and 2 per cent aluminium, magnesium alloy at room temperature (20 deg. Cent.).

The results of this investigation may be briefly summarised as follows :

(*a*) For three materials, 0·5 per cent molybdenum steel at 550 deg. Cent., commercially pure copper at 250 deg. Cent., and Nimonic 75 at 650 deg. Cent., which exhibited general and progressive crack propagation during tertiary creep, the stress criterion of fracture time was the maximum principal stress. Tertiary creep strain was for these materials an exponential function of maximum principal stress and time. Such materials showed anisotropy in tertiary creep, exhibiting all varieties of fracture in the case of 0·5 per cent molybdenum steel at 350 deg. Cent., and intercrystalline fracture only in the case of copper at 250 deg. Cent., and Nimonic 75 at 650 deg. Cent.

(*b*) For three materials, RR59 aluminium alloy at 200 deg. Cent., 0·2 per cent C steel at 450 deg. Cent., and magnesium (2 per cent aluminium) alloy at 20 deg. Cent., which exhibited no microscopically visible cracking at any position other than the site of eventual fracture, the stress criterion of the time to fracture was the Mises invariant stress, or octahedral stressl. In the case of RR59 aluminium alloy and the 0·2 per cent C steel, tertiary creep strain was a function of the Mises invariant stress or octahedral stress, the same actual functions of stress being involved as for primary creep. In the case of the magnesium alloy, primary creep continued to within a short period of fracture. The fracture of RR59 alloy at 200 deg. Cent. was intercrystalline, and the creep strain was isotropic. The other two materials showed transcrystalline fracture, and anisotropy of strain.

(*c*) It seemed reasonable to conclude that, while materials showing general and gradual propagation of cracks during tertiary creep will fail in a period proportional to the maximum principal stress, those in which no discernible cracking occurs in tertiary creep except as the immediate point of failure will fracture in a period proportional to the octahedral stress. Now there are practical circumstances in which materials may undergo tertiary creep strain, and fracture under complex stress systems, in which they are also subjected to vibratory stress. This of course may be vibratory stress of similar stress system, or of a differing stress system. However, provided it be possible to ascertain the total applied unit stresses at all times, these two cases present no real differences.

It is obvious that it is very important to examine the effect of vibratory stress on

* National Engineering Laboratory, East Kilbride, Glasgow.

the course of tertiary creep to fracture, in relation both to those materials which, in pure creep, are of the cracking variety dependent on maximum principal stress, and those which, in pure creep, are of the non-cracking variety dependent on the octahedral or second invariant stress. Accordingly an investigation of this matter was undertaken using a material representative of each of the above-mentioned groups of materials. As the representative of the cracking group of materials, copper at 250 deg. Cent. was chosen, while to represent the "non-cracking" group of materials RR 59 aluminium alloy at 200 deg. Cent. was chosen. The following paragraphs describe the results obtained in this investigation in relation to the copper at 250 deg. Cent.

Outline of Investigation

In the first place, it was decided to limit the investigation to an examination of the effect of vibratory stress on the time to fracture under complex stress systems, and not to examine any effects upon the characteristics of tertiary creep strain. This decision was largely prompted by the anticipated difficulties of measuring complex stress creep strain under conditions of vibration, and the consequent likelihood of having to spend considerable time in developing adequate strain measuring equipment. Apart from this, however, it was thought that the simple fracture-time information would probably in itself indicate the degree of advantage to be gained from an investigation of tertiary creep strain under these circumstances, and consequently lead to an avoidance of redundant work in any further programme decided upon.

The characteristics of the complex stress creep fracture-time relationship for conditions of pure creep were well established for moderate and lower stresses by previous complex stress pure creep tests carried out in complex stress creep units. These characteristics comprised a linear relationship between maximum principal stress, and log time. However, it was necessary to supplement this information with other tests at higher stress levels. These tests are referred to in later paragraphs.

To carry out the combined creep and fatigue tests necessary to examine the effect of vibratory stress on the stress time to fracture relations, use was made of a tension-torsion machine designed by the Sonntag Scientific Corporation of America, and capable of applying simultaneously mean and alternating loads in a variety of combinations of tension and torsion, or as separate simple tension and torsion.

The comparison with the results of pure complex stress creep tests was made by using the following systems :

(i) Creep stress plus one-third fatigue stress (i.e. the magnitude of the fatigue stress† of whatever variety was one-third of the corresponding creep stress).

(ii) Creep stress plus two-thirds fatigue stress.

(iii) Pure fatigue stress.

For each of these combinations of creep and fatigue, tests were made under stress systems corresponding to pure tension t, pure shear s, and ratios of t/s of value 2, 1 and 0·5.‡ In all combined tension and torsion tests the ratio t/s was made the same for both mean stress and alternating stress.

Within the range of these stress systems, individual tests were chosen at such stress levels as to give a reasonable range of fracture times. Thus it was hoped to obtain for whatever stress function was found to be the criterion of combined creep and fatigue, or for the pure fatigue regimes, a continuous plot of criterion stress function against time, as had been obtained in the case of pure creep tests described in reference 1. To achieve this end a series of plots were of course made for various possible stress functions as in the case of the pure complex stress creep tests. In the case of combined creep and fatigue, however, it was necessary to decide upon some convention to relate creep and fatigue under the criterion stress. Since obviously the simple creep stress was inadequate for this purpose two modes of relation were used, these being :

(i) Creep stress plus maximum value of fatigue stress.

(ii) Creep stress plus root mean square values of fatigue stress, i.e., creep stress plus 0·707 by maximum fatigue stress.

This choice was of course quite arbitrary.

The period of tests carried to fracture was limited to a maximum of 800 hours, this being a necessary step in view of the fact that only one combined stress fatigue machine was available.

Details of Materials, Specimens, and Testing Techniques

Materials.—The material was precisely similar to that used in the previously mentioned pure complex stress creep tests.[1] For the sake of completeness, some of the details of the condition of the material are recalled here. The copper used was in the form of 1½in diameter rolled bar of commercial standards of purity. Before use the material was heat-treated for one hour at 400 deg. Cent., and furnace cooled, and in this condition an average grain size of 0·09mm was obtained, this giving for the tubular specimen used in the tests (see later) an average of 10 grains to 15 grains to the wall thickness, which, in the light of previous creep work using tubular test pieces, was a sufficient number of grains to establish reasonably uniform and characteristic behaviour throughout the test piece cross section and length.

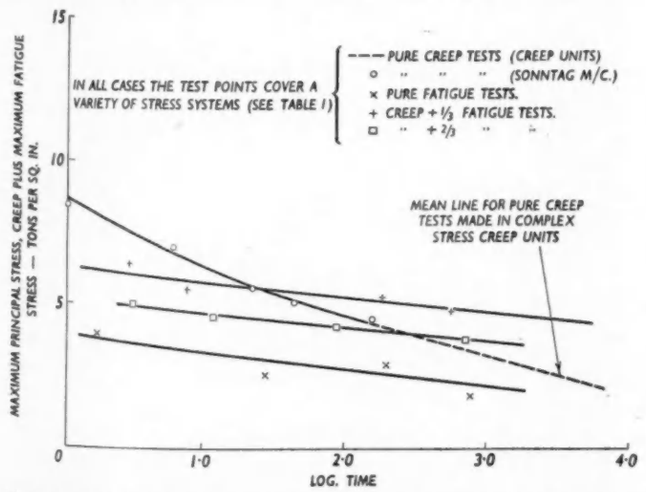
In regard to creep properties, a check on the initial isotropy of the material indicated that a high degree of isotropy existed. This isotropy was maintained under conditions of primary creep, but probably not in tertiary creep (although here some element of uncertainty existed).

As regards fatigue properties nothing was in fact known as to the isotropy or otherwise of the material, but, since the investigation was basically one of the effect of vibratory stress upon complex stress creep fracture, the view was taken that the fatigue anisotropy if present was part and parcel of the conditions imposed on the creep fracture by the added vibratory stress, and accordingly the fatigue anisotropy was not further investigated. However, general information which was available suggested that if fatigue anisotropy was present it was only of a small order of magnitude probably not greater than 10 per cent at moderate stresses. No evidence was afforded by subsequent tests that anisotropy arose in fatigue.

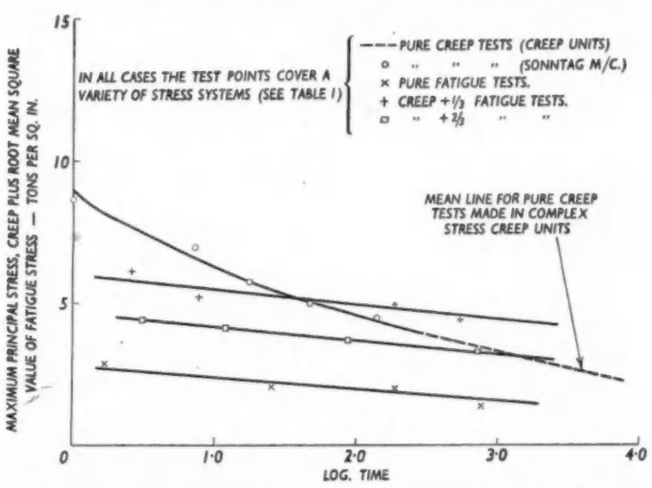
Specimens.—All the tests concerned in the present investigation, comprising combined tension and torsion, simple tension, and simple torsion, were made on tubular speimens 2·3in equivalent gauge length, 0·5in internal diameter, and 0·03in wall thickness. Loss of wall thickness by oxidation proved to be inappreciable.

Testing Techniques.—As previously stated the complex stress creep information available arose from tests previously carried out in NEL-type complex stress tensile and torsion creep units. The whole of the combined creep and fatigue tests, and also five pure creep tests, and four pure fatigue tests, were made in the combined tension and torsion creep and fatigue machine designed and built by the Sonntag Scientific Corporation of Greenwich, Connecticut, to a NEL specification, and described in a brochure issued by the

† i.e. semi-range value.
‡ Not necessarily all these systems were used in each case (i) to (iii).


MAXIMUM PRINCIPAL STRESS, CREEP PLUS MAXIMUM FATIGUE STRESS — TONS PER SQ. IN.
15
10
5
0
IN ALL CASES THE TEST POINTS COVER A VARIETY OF STRESS SYSTEMS (SEE TABLE I)
PURE CREEP TESTS (CREEP UNITS)
(SONNTAG M/C.)
PURE FATIGUE TESTS.
CREEP + ⅓ FATIGUE TESTS.
+ ⅔ " "
MEAN LINE FOR PURE CREEP TESTS MADE IN COMPLEX STRESS CREEP UNITS
1·0
2·0
3·0
4·0
LOG. TIME

(Left) Fig. 1—Relation between maximum principal stress and time to fracture. Maximum principal stress is taken as creep stress plus maximum fatigue stress


MAXIMUM PRINCIPAL STRESS, CREEP PLUS ROOT MEAN SQUARE VALUE OF FATIGUE STRESS — TONS PER SQ. IN.
15
10
5
0
IN ALL CASES THE TEST POINTS COVER A VARIETY OF STRESS SYSTEMS (SEE TABLE I)
PURE CREEP TESTS (CREEP UNITS)
(SONNTAG M/C.)
PURE FATIGUE TESTS.
CREEP + ⅓ FATIGUE TESTS.
+ ⅔ " "
MEAN LINE FOR PURE CREEP TESTS MADE IN COMPLEX STRESS CREEP UNITS
1·0
2·0
3·0
4·0
LOG. TIME

(Right) Fig. 2—Relation between maximum principal stress and time to fracture. Maximum principal stress is taken as creep stress plus the root mean square value of fatigue stress

Technical Contributors Section (*continued*)

TABLE I—*Complex Stress Creep and Fatigue Tests on Commercially Pure Copper at 250 deg. Cent.*

Description of tests	Ratio t/s	Tensile creep stress tons/in²	Shear creep stress tons/in²	Tensile fatigue stress† tons/in²	Shear fatigue stress† tons/in²	Creep m.p.s.* tons/in² A	Fatigue m.p.s.* tons/in² B	Root mean square value of fatigue m.p.s. tons/in² (0·707 of fatigue m.p.s. C	Total m.p.s.* tons/in² $A+B$	Total m.p.s.* tons/in² $A+C$	Fracture time hours
Pure creep...	∞	8·5	—	—	—	8·5	—	—	8·5	8·5	1·0
	∞	7·0	—	—	—	7·0	—	—	7·0	7·0	7·0
	∞	5·7	—	—	—	5·7	—	—	5·7	5·7	18·0
	∞	5·0	—	—	—	5·0	—	—	5·0	5·0	40·0
	∞	4·4	—	—	—	4·4	—	—	4·4	4·4	136·0
Pure fatigue	∞	—	—	1·67	0	—	1·67	1·18	1·67	1·18	596·0
	0	—	—	0	3·0	—	3·0	2·13	3·0	2·13	179·0
	2·0	—	—	3·5	1·75	—	4·22	2·99	4·22	2·99	2·0
	0·5	—	—	1·1	2·2	—	2·82	2·0	2·82	2·0	25·0
Creep + ⅓ fatigue	∞	5·0	—	1·67	—	5·0	1·67	1·18	6·67	6·18	2·0
	2·0	3·5	1·75	1·16	0·58	4·22	1·41	1·0	5·63	5·22	7·6
	1·0	2·2	2·2	0·73	0·73	3·56	1·19	0·84	4·75	4·4	545·0
	0·5	1·53	3·06	0·51	1·02	3·92	1·31	0·925	5·23	4·845	175·0
Creep + ⅓ fatigue	∞	3·0	0	2·0	0	3·0	2·0	1·41	5·0	4·41	3·2
	2·0	2·26	1·13	1·5	0·75	2·71	1·82	1·29	4·53	4·0	11·0
	1·0	1·48	1·48	1·0	1·0	2·4	1·6	1·13	4·0	3·53	84·0
	0·5	0·82	1·64	0·55	1·10	2·1	1·4	0·99	3·5	3·09	752·0

*m.p.s. = maximum principal stress. †Fatigue stress ± values given.

Baldwin-Lima-Hamilton Corporation under the title of " Tension-Torsion-Machine Serial No. —640–1281," of March 10, 1955. The detailed description of the machine can be read in the above-mentioned brochure ; here it is intended only to briefly outline the salient features of the machine.

The function of the machine is, of course, to test specimens in a suitable furnace at high temperature, under combined tension and torsion dynamic and static load. The axial loading capacity of the machine is static 0 to ±5000 lb, dynamic 0 to ±2500 lb. The torsional loading capacity is static 0 to ±400 lb per inch, dynamic 0 to ±400 lb per inch. The dynamic frequency is 1800 cycles per minute. The machine consists of two basic units, one unit generating the axial, static, and dynamic load, and the second (smaller) unit, mounted on top of the first one, generating the static and dynamic torsional loads. Both units are driven from one motor through a slip-free belt, so the vibratory axial and torsional loads are always in phase. Each system may be operated independently if desired. The axial static preload is maintained at a constant level throughout the test regardless of specimen yield. This is done electronically through a device involving a differential transformer. Torsional preload is, however, maintained constant by hand. For correct operation, it is necessary to hold motor speeds to a nearly constant value. This is achieved by use of an electronic speed control (" Mototrol " unit).

In using the above machine, temperature control of the usual accuracy of ±¼ deg. Cent. to ½ deg. Cent. was achieved by the use of Amsler type thermostats, and an electric furnace, and temperature gradients along the specimen were reduced to not greater than 3 deg. Cent. After test all specimens were subject to microscopical examination of the fractures, and regions surrounding the fracture.

Results of Tests

The complete results of the tests are embodied in Table I, and in Figs. 1, 2 and 7. Microphotographs of fractured specimens are shown in Figs. 3, 4, 5 and 6. Table I includes the results of five pure tensile creep tests which were made simply in order to extend the available complex stress creep data to the higher stress levels used in the combined creep and fatigue, or pure fatigue tests. The table also shows the results of four pure fatigue tests under respectively pure tension, pure torsion, and tension to torsion ratios of 2 and 0·5 for both mean and alternating stresses. Again it shows the results of four combined creep plus one-third fatigue stress tests under pure tension, and also tension to torsion ratios of 2, 1, and 0·5, and finally the results of four combined creep plus two-thirds fatigue stress tests under pure tension, and at tension to torsion ratios of 2, 1, and 0·5, in each case the t/s ratios applying to both mean and alternating stresses.

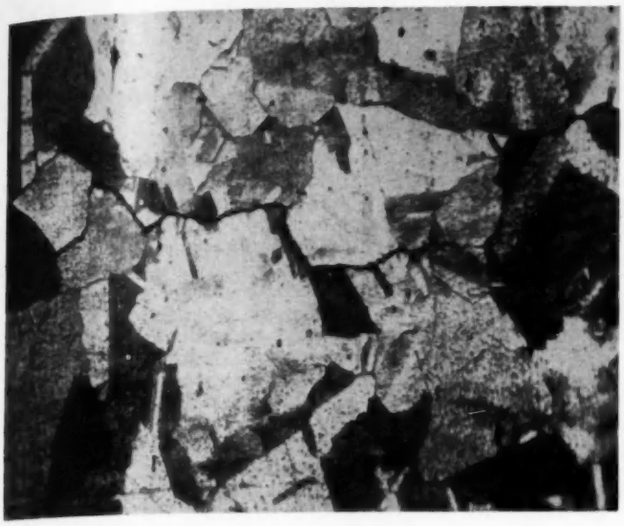
In Figs. 1 and 2 the results from Table I are plotted as total maximum principal stress against log time. In Fig. 1 the total maximum principal stress is the sum of creep stress plus maximum fatigue stress. In Fig. 2 the total maximum principal stress is the sum of creep stress plus the root mean square value of maximum fatigue stress. In Fig. 7 the relation between vibratory maximum principal stress and creep maximum principal stress for specific periods to fracture is shown.

Discussion of Results

As indicated previously in the text, the plot of maximum principal stress-time shown in Figs. 1 and 2 is one of several plots which were made of possible stress criteria against time. These possible criteria comprised those which had been examined for pure complex stress creep,[1] and were respectively (apart from maximum principal stress) the octahedral stress, the maximum shear stress, the hydrostatic stress and the maximum stress deviation-time plots. As for the particular case of pure complex stress creep, the only

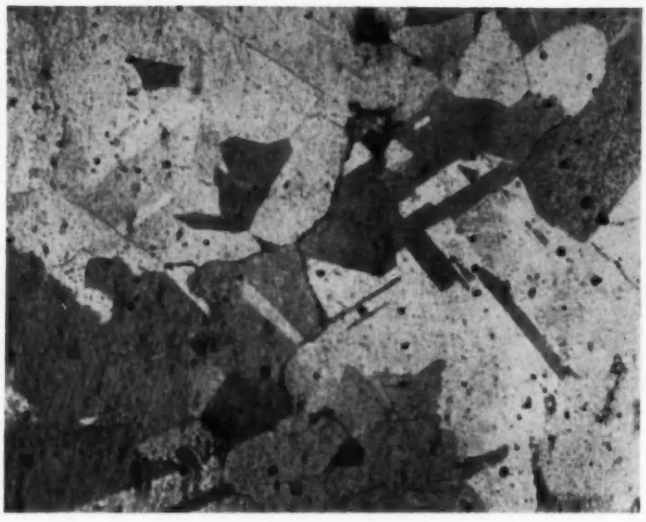
Fig. 3—Tensile creep test of commercially pure copper at 250 deg. Cent., tensile stress 4·4 tons per sq in. Micrograph (×230) taken near position of fracture

Fig. 4—Shear fatigue test of commercially pure copper at 250 deg. Cent., shear stress 3·0 tons per sq in. Micrograph (×230) taken near position of fracture



Tensile creep stress 1·53 tons per square inch. Shear creep stress 3·06 tons per square inch. Tensile fatigue stress 0·51 tons per square inch. Shear fatigue stress 1·02 tons per square in.

Fig. 5—Combined creep and fatigue test of commercially pure copper at 250 deg. Cent. Micrograph (×230) taken near position of fracture



Tensile creep stress 1·48 tons per square inch. Shear creep stress 1·48 tons per square inch. Tensile fatigue stress 1·0 tons per square inch. Shear fatigue stress 1·0 tons per square inch.

Fig. 6—Combined creep and fatigue test of commercially pure copper at 250 deg. Cent. Micrograph (×230) taken near position of fracture.

continuous plots were obtained for maximum principal stress-log time, and those are shown in Figs. 1 and 2.

Naturally some uncertainty arises as to what the plotted values of maximum principal stress should comprise. Obviously the pure creep or mean stress value of maximum principal stress is inadequate since the alternating fatigue stress must, in general, alter the fracture period. Again, while the sum of creep maximum principal stress, and the maximum value of the fatigue maximum principal stress is obviously a possibility, one feels that, since in half the fatigue cycle the alternating stress applied is compressive, the sum of stresses mentioned will not be the true criterion. In the absence of any other evidence it was decided that in addition to plotting the maximum principal stress as the sum of creep stress, and the maximum fatigue stress as in Fig. 1, the maximum principal stress should also be plotted as the sum of the mean creep stress, and the root mean square value of the fatigue maximum principal stress as in Fig. 2. The choice may be somewhat arbitrary, but it follows a convention adopted in other fields where an integrated effect of a cyclical function is to be evaluated.

Considering Fig. 1 in detail, we note the line which has been drawn to represent the relation between pure creep maximum principal stress, and log time for lower and moderate stress levels obtained in the combined stress creep units, and also the several points corresponding to higher stress level pure creep tests, carried out in the Sonntag machine. It will be seen that a reasonable common curve may be drawn through both sets of data.

The three plots comprising four stress levels, and stress systems, and corresponding respectively to pure fatigue, creep plus one-third fatigue, and creep plus two-thirds fatigue, given in Fig. 1, shows in two cases some secondary scatter of points, although in one case such scatter is conspicuously absent. However, there can be little doubt that a representative mean straight line can be drawn through these families of points, and that these mean lines are quite closely parallel. In other words, for all applied systems containing some element of fatigue stress, the characteristics are similar, except for an arithmetical factor depending on the degree of fatigue stress present.

It is noted further that these three parallel lines are not parallel to the curve corresponding to pure complex stress creep, but are crossed by this curve, or by an extension of it. The pure creep line crosses the creep plus one-third fatigue line at twenty hours roughly, while it crosses the creep plus two-thirds fatigue line at 400 hours. The pure creep and pure fatigue lines would seem likely to meet beyond 10^4 hours. The above figures would appear to mean physically that the life of the material is actually increased by the inclusion of an element of one-third fatigue stress in place of wholly mean creep stress of a given level at periods of life greater than a mere twenty hours, and is increased by a corresponding element of two-thirds fatigue stress for periods beyond 400 hours, provided the criterion stress be regarded as the creep maximum principal stress plus the maximum value of the fatigue maximum principal stress.

Turning to Fig. 2 in which creep maximum principal stress plus root mean square value of fatigue maximum principal stress is used as the criterion, it is seen that the pure creep line crosses the creep plus one-third fatigue line at about forty hours and the creep plus two-thirds fatigue line at somewhat beyond 10^3 hours, while the pure creep and pure fatigue lines seem likely to intersect well beyond 10^4 hours. Accordingly it appears that whatever convention for the significant maximum principal stress be adopted, the physical fact arises that, for life periods which increase as the proportion of fatigue stress present becomes greater, an actual increase of life of the material for a specific maximum principal stress, i.e. criterion stress, is produced over that corresponding to a pure creep stress, if the operative stress contains a proportion of fatigue stress.

In Fig. 7 the strengthening effect of a proportion of vibratory stress is clearly shown for a fracture period of 1000 hours.

It is interesting to note at this point that the attention of the authors had been drawn to the apparent strengthening effect of an element of fatigue stress combined with mean creep stress, in the case of members of the Nimonic group of metallic alloys, and that the authors have themselves found that Nimonic 75 material behaved in complex stress creep in a similar fashion to the currently considered commercially pure copper, i.e., it obeyed the maximum principal stress criterion of fracture, and showed general and continuously propagated cracking during tertiary creep.

Microphotographs of material of fractured specimens in the region of the actual fracture, and under respectively pure creep stress, pure fatigue stress, and two varieties of combined creep and fatigue stress are shown in Figs. 3, 4, 5 and 6. Consideration of these, and a considerable number of other microphotographs, gave several specific indications which may have some bearing on the problem in question. In the first place all cracking under all types of systems is intercrystalline in nature. Secondly, in pure creep, cracking started at points in the interior of the specimen cross section, and was relatively rough and wide in nature, considerable gaps existing between adjoining grains, and, in some cases, grains being encircled completely by cracks. On the other hand, in pure fatigue, cracking was of a very fine nature, starting from either the interior or exterior surfaces of the tube, and always running along a series of grain boundaries without encircling any individual grain.

In the case of the mixed states of stress, both varieties of cracking were present, the

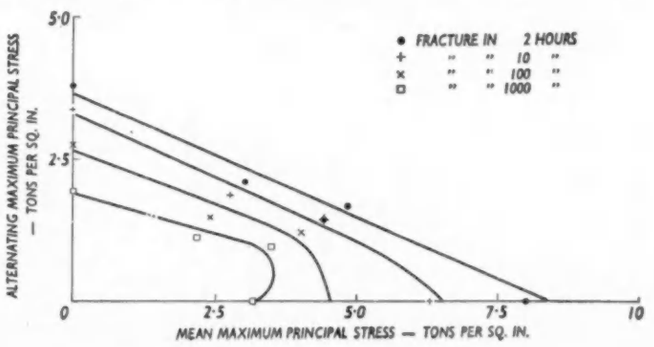


Fig. 7—Relation between alternating maximum principal stress and mean maximum principal stress for specific periods to fracture

Technical Contributors Section (*continued*)

degree of each variety depending upon the proportion of fatigue to creep stress present in the stress system. In all cases cracking was generally distributed.

It seems reasonable to surmise that the strengthening apparently arising, when at a specific criterion stress level, an element of creep stress is replaced by an equivalent fatigue stress, is physically connected with the replacement of coarse cracking by fine cracking, which occurs under these circumstances. However, further microphotographical examination is proceeding, which, in due course, may yield a more explicit reason for this strengthening effect.

Conclusions

(*a*) In the case of commercially pure copper at 250 deg. Cent., cracking of a generally distributed nature occurred under conditions of combined complex stress creep and fatigue, and under pure complex stress fatigue, as under pure complex stress creep, the cracking and final fracture being intercrystalline in all cases.

(*b*) For pure creep, cracking was relatively coarse, and commenced in the interior of the specimen, whereas, in pure fatigue, cracks were very fine, and started at the inner or outer surface of the tubular specimen. For combined states of creep and fatigue, proportions of each variety of crack were present, varying with the relative proportions of creep and fatigue stress.

(*c*) The stress criterion of the time to fracture was, in all cases, the maximum principal stress.

(*d*) For fracture periods greater than a certain order, an increase of the period for a given criterion stress level over that corresponding to a state of pure complex stress creep, was apparently attained if the stress contained a proportion of fatigue stress. The order of such periods increased with the proportion of fatigue stress present.

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A Surface Strain Extensometer for Use on Coal and Rock Underground

By O. H. CRITCHLEY, M.Sc., A.Inst.P.,* W. A. SAMMONS, B.Sc., A.Inst.P., and A. H. WILSON, B.Sc.

Modern coal-winning machines have high rates of extraction, and, with the more rapid removal of coal from its seams, new problems of roof support and underground rock movements have arisen. If these machines are to be used at full efficiency and with safety, a fuller and more exact knowledge of the forces that act on underground strata and the consequent rock displacements around mine excavations is needed than heretofore. For these investigations, measuring apparatus is required, but the design of such instruments for use in safety-lamp mines presents special difficulties. Not only must they be very robust and easy to operate in cramped and unpleasant conditions, but also they must be either "intrinsically safe" or "flameproof"[1, 2, 3], and these requirements add greatly to the problems that normally face the instrument designer. Here a suitable instrument developed by the National Coal Board, Mining Research Establishment, is described and discussed. It may have applications elsewhere than in coal-mines.

1. Introduction

THE need for a special surface extensometer arose in the East Midlands Division of the National Coal Board, when it was found necessary to study the strain in roof beds on long-wall faces supported by hydraulic chocks. Various approaches to the problem were considered, including the use of mechanical, vibrating wire, inductive and electrical strain gauge devices. The mechanical extensometer was rejected, as the conditions were such that it could not be left *in situ* and would have to be applied manually at each observation. As mining operations would be under way, freedom of access at the face was restricted, and the gauge points would generally not be accessible for application of the instrument. Some facility for remote reading was essential. Vibrating wire and inductive extensometers, although available commercially and attractive for the purpose, had to be ruled out because the associated indicating apparatus was not intrinsically safe. Unbonded strain gauge instruments were thought to be too delicate, and much laboratory work would be required to make them otherwise.

In contrast, bonded electrical resistance strain gauges were reasonably cheap and had been used successfully underground in load-measuring apparatus. Moreover, skilled personnel were available with special experience in this connection. It was, therefore, decided to use the bonded electrical resistance strain gauge as the basis of the surface strain-measuring instrument. The approach was to transmit the changes of strain in the exposed stratum directly to a thin and compliant metal strip with strain gauges bonded to it. To effect this, bolts were set in the exposed surface of the rock, and a sensitised metal strip was held in tension between them. Changes in roof strain would then be reproduced in the metal strip and affect the strain gauges.

The roof bed or other exposed rock stratum in which the strain is to be examined may be assumed to be a thick layer of homogeneous elastic material under uniform stress. The rigid pegs or bolts are set securely in the rock, so that they stick out through the surface with their axes perpendicular to it. Now, if the strain in the rock alters, the relative displacement of the protruding bolt shanks will correspond to the component of the strain variation in the plane of the pegs. If two metal yokes are secured to these pegs, and a thin and compliant strip of metal foil is stretched between them so as to be in tension, then changes of strain in the rock will give rise to similar changes of strain in the strip. The component of the main strain in the direction of the strip and the derived strain will be related by a proportionality factor, which is the ratio of the spacing between the axes of the pegs to the active length of the foil strip. The strain variation in the strip, either positive or negative, is detected by electrical resistance strain gauges bonded to it. Thus, the changes of surface strain in the layer, which in this case is either rock or coal stratum, may be determined in terms of the derived strain in the strip.

If the condition of stressing is that defined above, then the induced strain is directly proportional to the strain in the surface of the material. On the other hand, if the layer is subject instead to bending moment, there will be a strain gradient, and the relationship between surface and derived strains will not be so simple. For many mining purposes, it is possible to ignore the difference, because the stratum is thick; the strip is held close to the surface of rock; the depth of penetration of the bolts is relatively small and the radius of curvature of the bending is comparatively large.

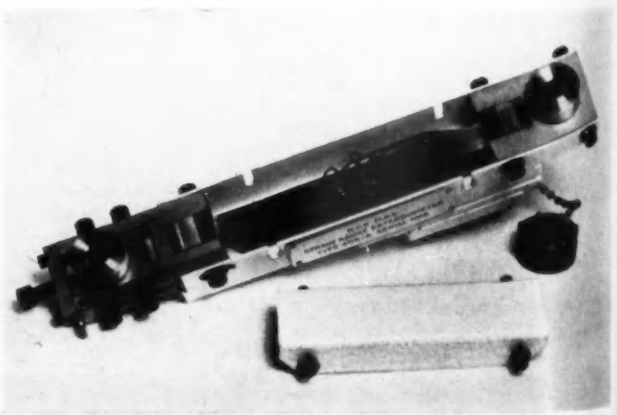


Fig. 1 — M.R.E. strain gauge extensometer, type 406A

* Now with Inspectorate of Nuclear Installations, Ministry of Power.

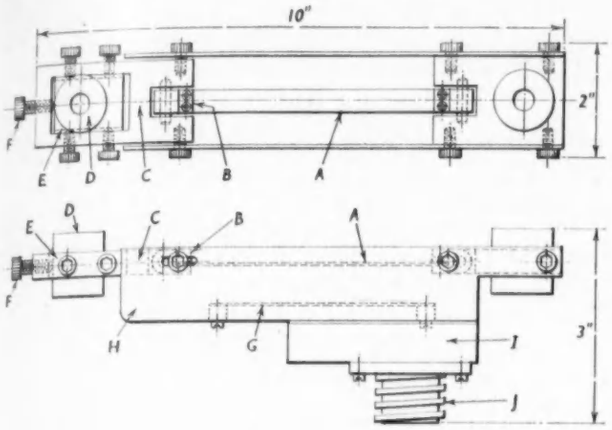


Fig. 2—Sketch of extensometer showing details

2. Description of the Extensometer

The present model of the M.R.E. strain gauge extensometer, type 406A, is illustrated both in construction and application in Figs. 1, 2, 3 and 4. The first is a reproduction of a photograph of the instrument, giving a view of its interior ; the second is a sketch showing the details of the assembly ; the third is a circuit diagram ; while the last is a pictorial representation of the device, fitted to a rock surface.

As shown in Fig. 2, the general assembly drawing, it consists of a strip of beryllium copper (*A*) $\frac{1}{2}$in wide, 0·005in thick and 4$\frac{3}{4}$in long, stretched between two end yokes (*C*). Stout copper lugs (*B*) are sweated to each end of the strip, and these are attached to each end yoke, respectively, by socket-headed screws. In each yoke is a bush (*D*) with a $\frac{5}{16}$in clearance hole, through which a bolt tail passes when the instrument is being set up on a rock surface. One of the bushes is fixed to a sliding piece (*E*), so as to permit pretensioning of the strip with an adjustment screw (*F*), when the extensometer is fixed in position.

The active strain gauges are attached to the strip. Two Saunders-Roe 1in linear foil gauges of 55 ohms resistance are bonded to each side, a pair of gauges in parallel constituting one arm of a Wheatstone bridge, of which the circuit is shown in Fig. 3. To give temperature compensation, the gauges comprising the two other arms are attached to a piece of the same material as that used for the strain sensitive strip. The component (*G*) is 4in long and is screwed to the brass protecting case (*H*). This case, which forms the body of the instrument, is screwed to the yokes (*C*) at each end and protects the strips against mechanical damage, as well as shielding them from air currents, thus improving the thermal stability. It is released at one end when in use, so that it does not introduce any rigidity in parallel with the strip

Four leads from the apices of the bridge are taken to the pins of a Plessey, Mk. IV, brass, coarse thread, fixed socket (*J*). As the whole bridge is enclosed within the body of the instrument, there is no trouble from variation of contact at the pins of the connector, since these small resistances are merely in series with the much higher resistance of the bridge. Simple plug and socket connections are then made to the measuring apparatus, the M.R.E. tester, type 404, which is a d.c. galvanometer and battery strain gauge test set, having a Ministry of Power Certificate of Intrinsic Safety.[4]

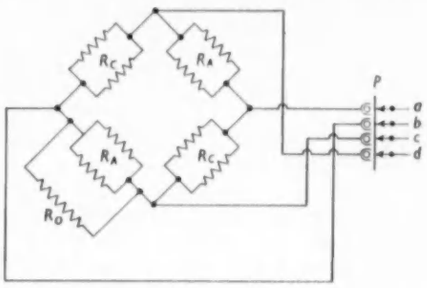
When the extensometer is in position, bolted to a rock surface, as shown in Fig. 4, it is necessary for the strip to be under pretension, and a device has been included so that the bridge can be balanced with a tensile strain of, say, 750 microunits. This is effected by connecting a resistor in shunt with one of the arms of the bridge of such a magnitude to give balance with the strip tightened up to the correct prestrain. The resistor of about 20,000 ohms is enclosed in a small box (*I* of Fig. 2) screwed to the underside of the instrument, giving ready access if adjustment becomes necessary.

3. Underground Installation of the Extensometer

The end yokes of the extensometer are attached to two stout pegs, which are embedded to a depth of 5in in the strata in which it is desired to study the strain changes during mining operations. These are two modified steel steel Rawl-bolts (Fig. 5) of $\frac{5}{16}$in diameter and 6$\frac{1}{2}$ in long. The modification consists of fitting a second expanding sleeve and thrust member at the threaded end of the bolt. Upon tightening up, both sleeves expand and the bolt is firmly held, not only at the top of the hole but also close to the extensometer end. This type of fitting is thought likely to give a reliable performance, as each bolt is firmly located in the rock at two places.

Two holes are drilled in the roof or other strata with the assistance of a jig. The rock surface around the hole is then faced with a tool, containing tungsten carbide inserts, which is fitted to the drill chuck. When the holes have been drilled and the rock surface is smooth and normal to the axis of the two holes, the special bolts are inserted. The instrument is then slipped over the protruding ends of the bolts and secured with nuts and washers, and the extensometer case released. A prototype unit was designed with four fixing holes, but was found difficult to install.

When the nuts are fully tightened, the end yokes are drawn up firmly against the surface of the rock with pressure sufficient to give a good frictional grip, so that the strata movements are transmitted without slip by direct surface contact. Although it is aimed to achieve this state when the extensometer is fitted, unless great care is taken one of two less desirable conditions may occur. In the better of these, the end yokes are pulled up against the collars which dilate the sleeves



R_A—Active gauges.
R_C—Compensating gauges.
P—Plug and socket connection.
a—*b*—To measuring instrument.
c—*d*—To applied voltage.
R_O—Bridge balancing resistance (approximately 20kΩ).

Fig. 3—Circuit diagram of strain gauge bridge

on the special Rawl-bolts, but with the sleeves, slightly proud, so as to lift the yokes clear of the surface of the rock. The strata movements are then communicated to the end yokes solely through the bolt tails, and the strain changes transmitted to the strip are diminished by bending of the bolts. The worse is an intermediate state, when the yokes are neither firmly gripped by the rock nor held by the bolts alone. In this condition, the yokes will slip on the rock surface and result in hysteresis, which has been observed to be as much as 15 per cent of the full range displacement.

After fitting the extensometer to the

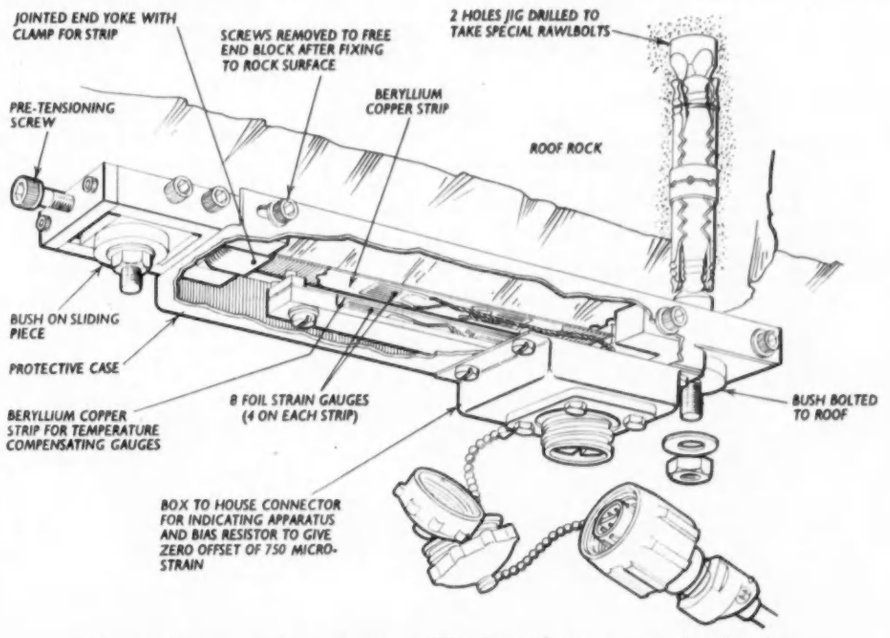

JOINTED END YOKE WITH CLAMP FOR STRIP
SCREWS REMOVED TO FREE END BLOCK AFTER FIXING TO ROCK SURFACE
2 HOLES JIG DRILLED TO TAKE SPECIAL RAWLBOLTS
PRE-TENSIONING SCREW
BERYLLIUM COPPER STRIP
ROOF ROCK
BUSH ON SLIDING PIECE
PROTECTIVE CASE
8 FOIL STRAIN GAUGES (4 ON EACH STRIP)
BUSH BOLTED TO ROOF
BERYLLIUM COPPER STRIP FOR TEMPERATURE COMPENSATING GAUGES
BOX TO HOUSE CONNECTOR FOR INDICATING APPARATUS AND BIAS RESISTOR TO GIVE ZERO OFFSET OF 750 MICRO-STRAIN

Fig. 4—Strain gauge extensometer, type 406A, fitted for measurement of roof strain

Technical Contributors Section (*continued*)

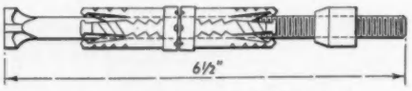


Fig. 5—Sketch of modified Rawl-bolt

surface in which the strain changes are to be studied, it is usual to bring its output to zero by adjustment of the pretensioning screw. As the null balance for the strain gauge bridge has already been offset to about 750 microstrain by the resistive shunt across one of the arms, the pretension allows both positive and negative strain increments to be observed. The instrument may either be read by a strain gauge test set,[4] plugged into the Plessey outlet socket at the required intervals, or groups of extensometers may be connected to a central recording station for the duration of the experiment.

4. Calibration

The law of the instrument may be readily deduced from the well-known formula for a strain gauge bridge with two active arms and, thus, the open circuit output across the appropriate bridge diagonals,

$$\delta e = F\left(\frac{\varepsilon_1 k V}{2}\right) \quad . \ . \ . \quad (4.1)$$

where

ε_1 = strain in the rock

k = strain gauge factor

V = energising p.d., and

F = strain multiplication factor, which is the ratio of the spacing between the bolts in the rock to the length of the foil strip.

For the extensometer, type 406A, using Saunders-Roe linear foil strain gauges,* the sensitivity thus calculated is 1·8 microvolts per microstrain in the rock per volt applied to the bridge. Surprisingly, this prediction is considerably at variance with experimental results, and it is necessary to introduce a coefficient, η, called the "Strain Loss Factor." The corrected law is, therefore :

$$\delta e = \frac{F}{\eta} \cdot \frac{kV}{2} \cdot \varepsilon_1 \quad . \ . \ . \quad (4.2)$$

and the average working sensitivity is 1·2 microvolts per microstrain in the rock per volt bridge excitation, the exact figure being peculiar to a given instrument.

For work in the field, it has been found convenient to calibrate the instruments in terms of the factor, η, introduced into Equation (4.2) above. This "Strain Loss Factor," which must be determined empirically, is characteristic of the given instrument, and may be defined as :

$$\eta = \frac{\text{True strain in the surface}}{\text{Indicated strain}}$$

To determine η, each extensometer is calibrated separately in a test jig, where it is fitted on a pair of bolts, fixed firmly in a block of rock, and the predetermined pretension to be used underground is applied. The block is then compressed in a load-testing machine, and the readings from the extensometer are compared with readings of surface strain on the rock itself, measured by resistance strain gauges stuck on the surface between the bolts, and also with measurements of strain on the block taken with a mechanical extensometer. It has been found that there is considerable variation between extensometers. For one series of calibrations involving fifteen instruments, the mean value of η was found to be $1{\cdot}5 \pm 0{\cdot}1$, so that η for any instrument may be expected to lie between 1·2 and 1·8. Later work has confirmed this result.

Nevertheless, the "Strain Loss Factor" when determined for a given instrument is consistent from one test to the next, provided that the conditions of fixing are not varied. Statistical analysis of experimental results has shown that the function $(\sigma_n/\eta_n \times 100$ per cent) is not greater than ± 5 per cent where σ_n is the standard deviation of η_n for the extensometer numbered n.

Hence, the "Strain Loss Factor" for an extensometer used for a series of measurements may be relied upon to ± 10 per cent with 95 per cent of the results lying within these bounds of error.

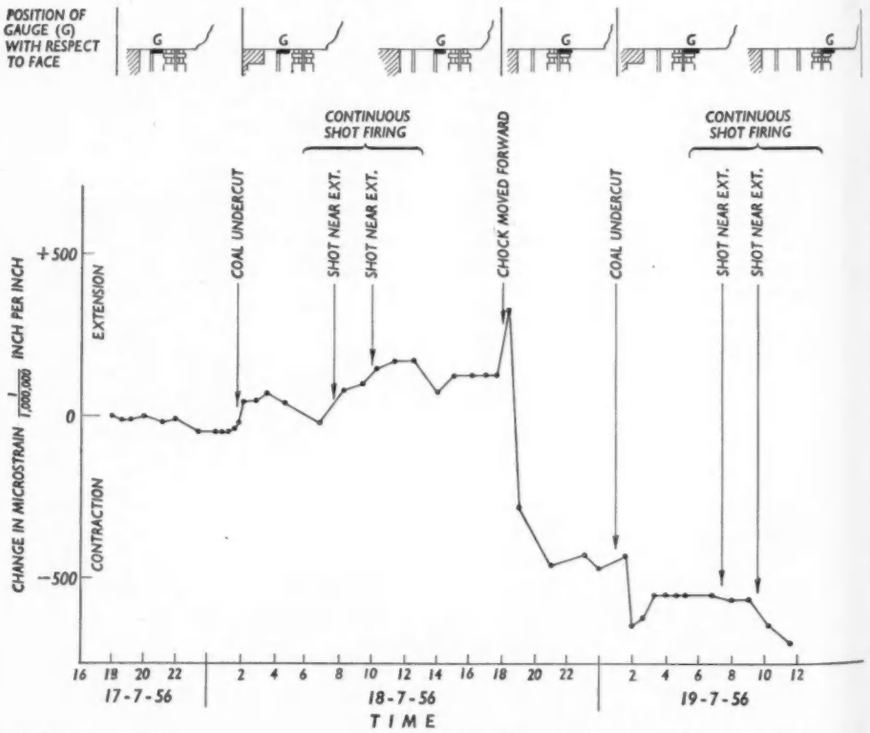
5. Factors Contributing to the Strain Loss

As the practical results and those predicted from theory are not concordant, there must be important factors that influence the sensitivity of the extensometer. A clear understanding of the causes of the strain loss is needed, not only for confident use of the instrument, but also to see if any alteration to the design may be desirable. For these reasons, a thorough study of the causes of the discrepancy was undertaken, but, as the full theory is complicated, only a qualitative discussion will be given here.

The basic assumptions made, when the extensometer was conceived, were that the thin metal strip carrying the strain gauges would be very compliant, that any changes in its condition of strain would be determined almost entirely by rock movements transmitted to it by the "inflexible" pegs to which it was attached, and that this induced strain would in fact be sensed by the gauges.

It has been shown that the "Strain Loss Factor" for a given instrument may be expected to lie between 1·2 and 1·8, with occasional higher values, and it is surprising that there is this large discrepancy between the true and indicated strain. Among the factors that may contribute to this are yield in the mechanical linkages between the thin metal strip and the rock, and local strengthening of the metal foil by the strain gauges, layers of adhesive and protective coatings. Further, if the extensometer is not clamped firmly against the rock surface, then all, or part of, the tension in the strip will be applied to the bolts, which will bend under the load and add to the error.

In order to make the strip compliant, it was chosen as thin as was compatible with practical design. Consequently, the thickness of the adhesive with which the gauges are attached will, in general, be several times the thickness of the foil, especially if, in addition, a protective coating of adhesive is applied over the top of the gauge. Thus, when the strip is in tension, its longitudinal strain distribution is not uniform, since the gauged portion has a different modulus of elasticity and is subject to a different stress. This gives a strain indication from the gauges, which, when allowance has been made for the difference in lengths of the strip and the bolt separation, is found to be lower than it would be if the properties of the strip were unaffected by the adhesive.



Depth of seam : 1200ft.
Height of seam : 4ft.
Method of working : On the advance by undercutting, blowing down and hand loading ; total caving.
Type of support : Dowty props with wood chocks along waste edge.
Roof : Well bedded sandstone free of cutter breaks.

Fig. 6—Bolted strip S.G. extensometer, type 406, change in roof strain normal to face, Eureka seam, Rawdon colliery

* The strain gauges used in the extensometer, type 406A, are Saunders-Roe 1in linear foil elements, type 1/Lin/55, having the following properties : Resistance, 55 ohms ; Foil material, 0·001in "Ferry," a 55/45 copper-nickel alloy also known as "Eureka," "Constantan" or "Advance"; Gauge factor, 2·10 ; Backing material, Epoxy-ethylene ; Total thickness, 0·003in approximately ; Form, Grid of twenty lines, 0·90in long, 0·0075in wide and spaced by 0·0075in ; Temperature coefficient of resistance, −10 parts in 10^6 per degree Celsius.

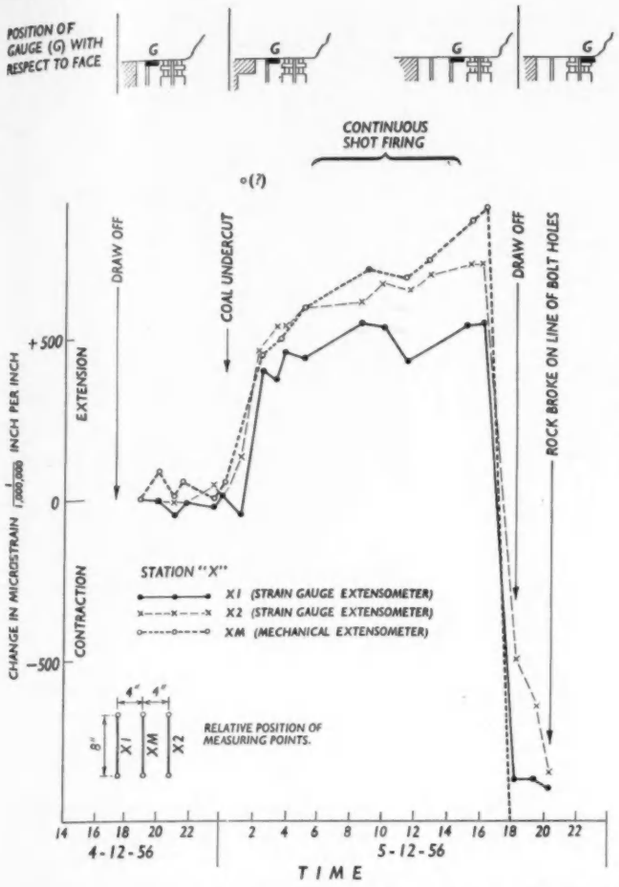


Fig. 7—Second trial, six bolted strip S.G. extensometers, type 406, change in roof strain normal to face, Eureka seam, Rawdon colliery

Although most of the strain loss may be attributed to the effect of local strengthening of the foil by adhesive and strain gauges, there is a residual for which this theory does not account, and it is necessary to consider contributions to the strain loss from the linkages. Reference should be made to Section 7 for a more comprehensive first order treatment, in which an attempt is made to treat the problem analytically.

6. Field Trials

The extensometer has been subjected to underground trials during all the stages of its development. The first of these was at Rawdon Colliery, near Ashby-de-la-Zouch, when the prototype unit type 406 was attached to the roof of the Eureka seam. The changes of strain were observed from the time of its attachment as close as possible to the coal face itself, until it had to be removed to prevent its loss in the waste. The results and the correlated sequence of mining operations are shown in Fig. 6.

Six extensometers, type 406, were available for a second field trial, also carried out at Rawdon Colliery. The instruments were set in the roof at three stations along the face in pairs, 8in apart, so that some check on the reliability of their readings could be obtained. In addition, measurements were made with a hand-held mechanical extensometer (Demec). The results from one of these stations are plotted in Fig. 7. The close agreement between results from adjacent extensometers was taken as an indication that the instruments were reliable underground. Calibration of the extensometers in the laboratory, before and after the field trial, also gave satisfactory agreement.

Since the proving trials reported above, more extensometers have been made and have given satisfactory performances during a number of underground studies of strata behaviour. They have also been successfully used in groups and read remotely from a central observation point.

7. A First Order Analysis of the Phenomenon of Strain Loss

The simple and straightforward explanation of strain loss in the instrument, which is given earlier, does not provide the quantitative approach needed if the design is to be changed to minimise the effect. Unfortunately, a full and rigorous analysis is not only lengthy, but is also complicated, and at the time of writing it had not been fully worked out. Nevertheless, an attempt is made here to present a first order theory and, although this does not give good quantitative agreement with the experimental data, it supports the qualitative arguments and throws light on important aspects of the design.

Effect of Gauges and Adhesives on the Foil Strip.—A simplified representation of the sensitised foil strip and the adhesive layers in the region of a strain gauge is given in Fig. 8. On the basis of this model, the approximate numerical value of the component of the "Strain Loss Factor," η, due to the effect of these adhesive layers is derived below.

Let

η_A = the required component of strain loss, and suppose

l = unstretched length of strip

a = length of cemented portion containing the gauges

d_f = thickness of foil

d_a = thickness of cemented portion considered as a single unit

E_f = modulus of elasticity of foil

E_a = modulus of elasticity of cement

E = modulus of elasticity of cemented portion of the strip

ϵ_1 = true surface strain

ϵ_2 = strain indicated by gauges on strip.

The modulus of elasticity, E, for a modified strip is that for a laminated material, considered in the direction of the layers, and is given by

$$E = \frac{d}{d_f + d_a} \frac{E_f + d_a E_a}{} \quad . \; . \; . \quad (7.1)$$

By equating expressions for the changes in length of the separate parts of the strip to its total extension, an expression is derived :

$$\frac{\epsilon_1}{\epsilon_2} = 1 + \left(\frac{d_a E_a}{d_f E_f}\right)\left(1 - \frac{a}{l}\right). \quad . \quad (7.2)$$

i.e.

$$\eta_A = 1 + \delta$$

where

$$\delta = \left(\frac{d_a E_a}{d_f E_f}\right)\left(1 - \frac{a}{l}\right) \quad . \; . \quad (7.3)$$

Now, as $a < l$, δ is always positive. Hence $\eta_A > 1$ and $\epsilon_1 > \epsilon_2$. The effect of the adhesive coatings on the strip is, then, to make the indicated strain ϵ_2 less than the true surface strain ϵ_1, and, thus, there is a "strain loss" which is in agreement with experiment.

While the concept of the "Strain Loss Factor" is convenient for the user of the extensometer, study of the fractional error in strain indication may give a simpler insight into the physics of the instrument.

The fractional error in the indicated strain is :

$$\frac{\epsilon_1 - \epsilon_2}{\epsilon_1} = \frac{\delta}{1 + \delta} \quad . \; . \; . \quad (7.4)$$

This function increases with δ and, for a given (a/l) the error increases with the term $(d_a E_a)/(d_f E_f)$ in Equation (7.3), showing that to minimise the error, the strip should be made from a metal with a high modulus of elasticity, E_f.

A set of curves is given in Fig. 9, displaying the relation between error and foil thickness for two practical materials, namely beryllium-copper and steel. The adhesive is "Araldite" strain gauge cement. (See footnote for values of the various elastic moduli[5].)

In a practical case, where the total thickness of the combination of adhesive, gauges and protective coatings might be 0·023in on a 0·005in beryllium-copper strip, reference to the family of curves in Fig. 9 shows that the fractional error in strain indication should be 11 per cent, or $\eta = 1 \cdot 1$. However, it has been found by experiment that the expected error for such an extensometer is 34 per cent, or $\eta = 1 \cdot 5$. Clearly, while the adhesive layers contribute to the "strain loss," there are other important influences to be considered.

Effect of Bending of the Fixing Bolts.—It has been assumed, so far, that the extensometer has been drawn up tightly against the rock surface, so that the strata movements are transmitted without slip. If this is not the case then the fixing bolts will bend under the strip tension, as indicated in Fig. 11, and there will be a further "strain loss." As this can occur in practice, it will be useful to assess the additional error that may arise.

In the following "idealised" treatment of the phenomenon, it is assumed that the strip

	Young's modulus (lb per square inch)
Beryllium-copper	18×10^6
"Ferry"—55/45 copper-nickel	20×10^6
Steel	30×10^6
"Araldite" strain gauge cement	1×10^6

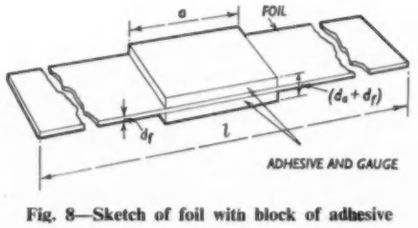
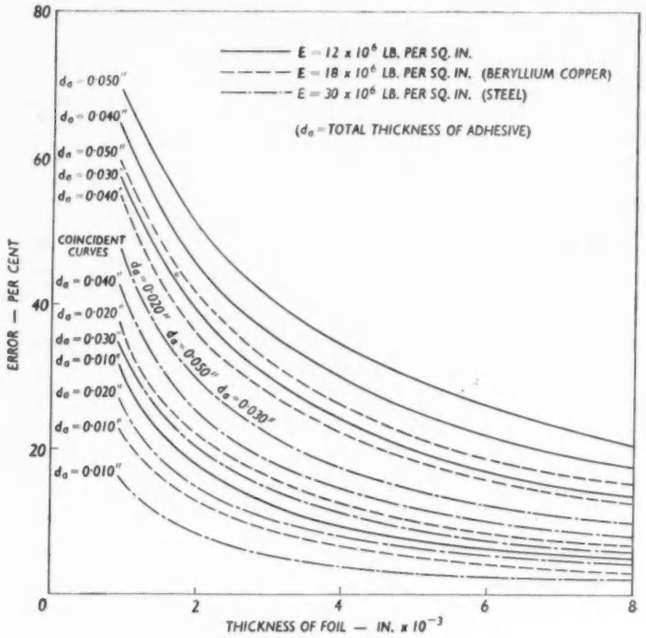


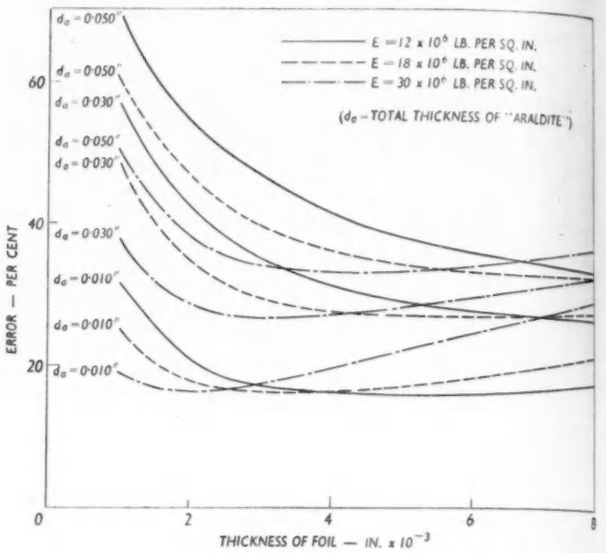
Fig. 8—Sketch of foil with block of adhesive

Technical Contributors Section (*continued*)


E = 12 x 10⁶ LB. PER SQ. IN.
E = 18 x 10⁶ LB. PER SQ. IN. (BERYLLIUM COPPER)
E = 30 x 10⁶ LB. PER SQ. IN. (STEEL)
(d_a = TOTAL THICKNESS OF ADHESIVE)
COINCIDENT CURVES
ERROR — PER CENT
THICKNESS OF FOIL — IN. x 10⁻³

(Left)—Fig. 9—Error due to modification of strip by adhesive

(Below)—Fig. 10—Total error in readings due to strengthening of strip and bending of bolts


E = 12 x 10⁶ LB. PER SQ. IN.
E = 18 x 10⁶ LB. PER SQ. IN.
E = 30 x 10⁶ LB. PER SQ. IN.
(d_a = TOTAL THICKNESS OF "ARALDITE")
ERROR — PER CENT
THICKNESS OF FOIL — IN. x 10⁻³

occupies the full interval between the bolts, and that it is not strengthened by the gauges and cement layer. As a further simplification, bending above the rock surface only is considered, and movement of the bolt shank is not restrained by the collar. This simple arrangement is shown in Fig. 10.

Now, assume in the first static condition that with some existing tension, T, in the strip, the deflection of each bolt is $\delta y/2$.

Let

$(l+\delta l)$ = stretched length of strip

x = distance apart of the ends *P-P* of the bolts

E_b = modulus of elasticity of the bolt material

I = second moment of area of cross-section of bolt about a diameter

L = length of bolt between surface and strip

b_f = width of strip.

The strain in the strip due to the initial tension is

$$\frac{\delta l}{l}=\frac{T}{b_f d_f E_f} \quad . \quad . \quad . \quad (7.5)$$

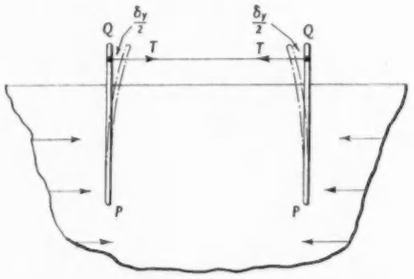


Fig. 11—Sketch showing bending of bolts

Let the rock experience an increment of compressive stress in the direction shown, so that the bolts move together a distance, δx, such that the tension in the strip is reduced to zero. Then the strain in the rock, as seen by the bolts at their ends *P-P*, is

$$\varepsilon_1{}^1=\frac{\delta x}{x}=\frac{\delta x}{l}$$

to a first approximation

The resulting change of strain in the strip and at the bolt ends, *Q-Q*, is

$$\varepsilon^1{}_2=\frac{\delta l}{l}$$

Now

$$\eta_b=\frac{\varepsilon_1{}^1}{\varepsilon^1{}_2}$$

where η_b is the additional "Strain Loss Factor" attributable to the bending of the bolts, and, thus

$$\eta_b=\frac{\delta x}{\delta l}$$

since

$$\delta x=\delta l+\delta y$$

$$\eta_b=\frac{\delta l+\delta y}{\delta l}=1+\Delta \quad . \quad . \quad . \quad (7.6)$$

where

$$\Delta=\frac{\delta y}{\delta l}$$

Treating the length of bolt protruding between the surface and the strip as a simple cantilever,

$$\frac{\delta y}{2}=\frac{TL^3}{3E_b I}$$

and substituting for δl from Equation (7.5)

$$\Delta=\frac{2L^3 b_f}{3E_b I}d_f E_f \quad . \quad . \quad (7.7)$$

The added fractional error is

$$\frac{\varepsilon_1{}^1-\varepsilon^1{}_2}{\varepsilon_1{}^1}=\frac{\Delta}{1+\Delta} \quad . \quad . \quad . \quad . \quad (7.8)$$

Examination of the properties of Δ shows that it is directly proportional to the thickness and modulus of elasticity of the strip, and curves for its value for beryllium-copper and steel as a function of thickness are plotted in Fig. 12.

It may be concluded from this analysis that, for the minimum strain loss due to bolt yield, the strip should be relatively long, narrow, thin and of low elastic modulus, while the bolts should be stout and protrude for the minimum distance from the surface of the rock, this latter being especially important because the distance L appears in its third power in Equation (7.7).

Combined Effect.—Although the aim in fitting the extensometer is to clamp it so tightly to the rock that there will be no tangential loading of the bolts, the conclusions reached immediately above apply qualitatively even in the case of "perfect" fitting, because there will be yield in the mechanical linkages, i.e. bushes, yokes, end clamps, and this will introduce a strain loss error that will be analogous to that due to simple bending of the bolts. It is, therefore, valuable to examine the total error that arises from the combined effect of strengthening the strip with adhesives and bolt yield, as derived in expressions (7.4) and (7.8) respectively. This is displayed in Fig. 10, where it can be seen that some sort of compromise involving the choice of material and the thickness of the strip must be made, if the net error resulting from both sources is to be minimised.

Laboratory Experiments.—To test the conclusions reached in the last section, a testing rig, shown in Fig. 13, was made up. It

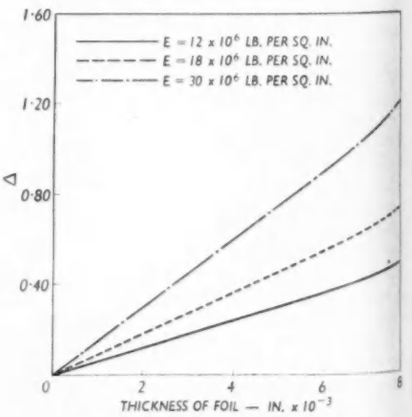


Fig. 12—Error due to bending of bolts

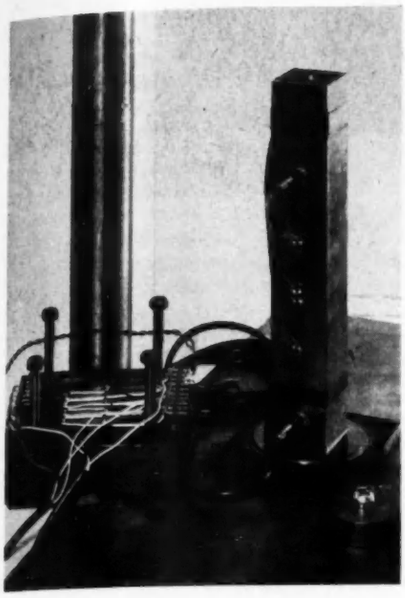


Fig. 13—Steel testing column

consisted of a block of mild steel, 12in high, with a square cross-section of side 2in. One face of the block carried two pegs, for fitting the extensometer, pressed in 8in apart. Between these pegs, equally spaced, four strain gauges were fixed to the surface. These were connected as four separate Wheatstone bridges, the dummy gauges being mounted on a second steel block placed alongside the test block on the platen of the press. The five strain gauge bridges, as well as the extensometer, were energised from a common battery, and their outputs fed into a multi-channel recording potentiometer (Fig. 14), which was also used to indicate continuously the p.d. applied to the bridges by sampling a known fraction of it.

It was found that provided the test block was loaded through a $\frac{3}{4}$in ball, the four gauges along the block agreed closely with one another. The maximum load was 40 tons, corresponding to a displacement between the bolts of 0·006in and a maximum true surface strain of 750×10^{-6}, or $18{\cdot}8\times10^{-6}$ per ton.

Several extensometers were tested, and their zero readings were found to repeat fairly well, varying from the initial value by not more than 2 per cent of the full-scale deflection.

Results are tabulated immediately below for a series of strips made up from two gauges of beryllium-copper sheet and three thicknesses of cement. The specimens were $\frac{1}{2}$in wide and 4·75in long and the net length of the cemented zones surrounding the strain gauges was taken to be 3in.

Strip No.	Thickness of foil (in)	Thickness of cement layers (in)	Observed fractional error	Strain loss factor (η)	
				Experimental	Calculated from Eq. (7·5)
1 ...	0·001	0·015	0·39	1·64	1·31
2 ...	0·001	0·015	0·36	1·56	1·31
3 ...	0·001	0·060	0·57	2·33	2·23
4 ...	0·001	0·070	0·64	2·78	2·44
5 ...	0·005	0·015	0·24	1·32	1·06

As the end yokes of the test extensometer were held securely against the sides of the test rig, the bolts would have experienced little tangential loading, and their bending has been ignored in calculating the theoretical "Strain Loss Factor," which has been attributed solely to the effect of the cement layers. Comparison between the experimental and calculated figures for the factor confirms that a large part of the strain loss is due to local strengthening of the strip by the layers of adhesive. It is noteworthy that the increase in thickness of cement from strip No. 1 to strip No. 4 corresponds with a decreasing difference between the empirical and theoretical values, which is further evidence of the effect of cements on the thin metal sheet forming the strip. Nevertheless, there is still a large residual error to be explained. While elastic yield in the linkages is, no doubt, important, strain gradients in the strip may also make a contribution.

8. Conclusions

The bolted strip strain gauge extensometer has been thoroughly proved in pit use, and its value as a robust and easily fitted device for measurement of surface strain in rock established. The pit trials have, of course, led to the introduction of a number of improvements, but the basic principles of the instrument are unaltered. The modifications have had the aim of making it quicker and easier to fit to the rock surface, simpler to adjust, and of giving better protection against the various hazards of the face area.

The present model, type 406A, has thus been demonstrated to be a valuable addition to the range of instruments for strata control investigations in coal-mines. Its accuracy of ±10 per cent is adequate for most mining purposes, and it seems likely that it may be quite widely employed for strain measurements where a sturdy and easily applied instrument is required, say, for a study of the behaviour of roadway arch supports. There is no reason why it should be restricted to mining applications, and it doubtless has many uses in the field of civil and other heavy engineering arts. Perhaps its outstanding feature is the fact that it may be applied to a structure irrespective of the condition of its surfaces.

The effect of bonding an electrical resistance strain gauge to a surface must not be ignored, as the strain pattern in it may be vitiated.

9. Acknowlegements

The authors wish to acknowledge the work of Mr. W. H. Kellet who contributed to the development of the instrument. They also wish to acknowledge the co-operation given by Mr. W. J. Adcock and the staff of the Strata Control Department of the East Midlands Division, National Coal Board. The authors are grateful to Dr. W. Idris Jones, Director General of Research, National Coal Board, for permission to publish this article. The views expressed are those of the authors and not necessarily those of the Board.

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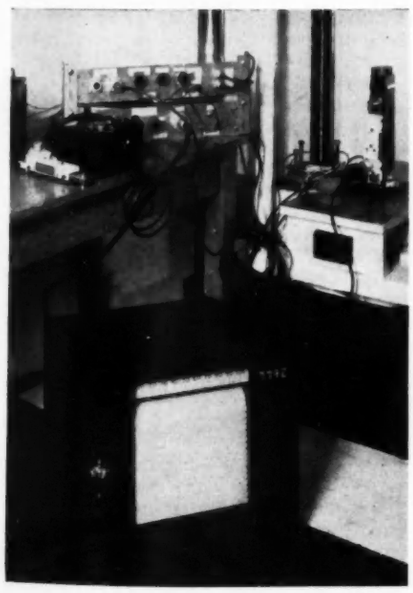


Fig. 14—Measuring apparatus for laboratory tests

Spherical Vessels Thermal and Pressure Stresses

By A. ORMEROD, B.Sc., D.I.C., A.M.I.Mech.E.*

WHEN a spherical vessel contains a hot fluid there are thermal stresses in the wall due to the temperature gradient, compressive at the internal surface, tensile at the external. If the fluid is under pressure tensile hoop stresses are set up throughout the wall. For small pressures the wall will be comparatively thin and simple approximate expressions can be used to determine the thermal and pressure stresses separately; these are added to give the total tensile stress at the external surface, the most highly stressed region.

For higher pressures, however, the wall must be made thicker and the simple approximation of uniform hoop stress due to the pressure is no longer accurate. The distribution of thermal stress also diverges from the simple pattern assumed in the thin-walled sphere and it becomes necessary to use more accurate methods for the evaluation of the stresses.

It would be convenient for design use to have an expression for the required wall thickness in terms of the fluid pressure, the temperature difference between the internal and external surfaces, and the maximum permissible stress in the material. It is the object of this article to develop such an expression in the simplest possible form.

The shape of the vessel will be defined by the ratio of the external radius R_2 to the internal radius R_1 and will be denoted by k $(=R_2/R_1)$.

* Royal Military College of Science

Pressure Stresses

The hoop stresses ρ_H and the radial stress ρ_R are set up by an internal pressure ρ can be read from the stress line diagram shown in Fig. 1. The tensile hoop stress at the internal surface is :

$\rho\,(\frac{1}{2}k^3+1)/(k^3-1)$ which with a radial compressive stress of ρ, gives a maximum shear stress of $\rho\frac{3}{2}k^3/(k^3-1)$. The tensile hoop stress at the external surface is :

$$\rho 1\tfrac{1}{2}/(k^3-1) \quad . \quad . \quad . \quad . \quad (1)$$

Technical Contributors Section (*continued*)

The most heavily stressed region is the internal surface, and when there is no thermal stress, if the safe working stress of the material in simple tension is denoted by f and the shear criterion of failure is used, the required thickness ratio can be found from the relation

$$\frac{3}{2}\rho k^3/(k^3-1)<f$$

or

$$\frac{3}{2}\rho/f+\frac{1}{k^3}<1 \quad . \quad . \quad . \quad . \quad (2)$$

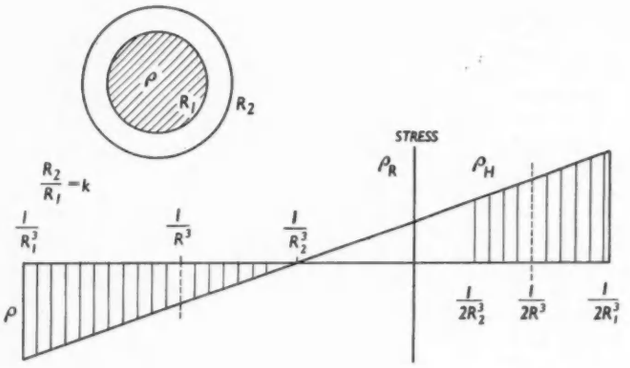


Fig. 1

It will be noticed that the thicker the sphere, the smaller is the hoop stress at the external surface relative to that at the internal surface. It is also of interest to note that no matter how thick the wall of a sphere may be the greatest safe internal pressure is $2/3\,f$.

Temperature Stresses

In a thin walled sphere with the internal surface T_1 deg. hotter than the external surface the temperature gradient may be assumed uniform and the wall is in uniform bending with a surface stress of $\frac{1}{2}E\alpha T_1/(1-\sigma)$, compression internally, tension externally. In this expression α is the coefficient of linear expansion of the material and σ is Poisson's ratio ; for brevity the complete expression will be denoted by t. For a sphere with thicker walls a more detailed analysis is necessary to determine the stresses, the first step being to define the temperature distribution.

Temperature Distribution.—Since a uniform change of temperature throughout the material does not cause any stress it is differences of temperature that are relevant rather than absolute values and any convenient point on the temperature scale may be chosen as zero. If the inner surface is maintained at a steady temperature T_1 higher than the outer, it is advantageous to define the temperatures as $+\frac{1}{2}T_1$ inner and $-\frac{1}{2}T_1$ outer ; the expressions derived may then be adapted to describe the reverse situation of a hot outer surface and a cold interior by merely changing the sign of T_1. This convention is indicated in Fig. 2.

With steady conditions there will be a constant radial flow of heat through the wall, i.e.

$$4\pi R^2\frac{dT}{dR}=\text{constant}$$

or

$$T=C_2-C_1/R$$

Evaluating the constants by putting in the surface condition leads to the equation :

$$T=T_1\{(R_2/R-1)/(k-1)-\tfrac{1}{2}\}$$

Temperature Stresses.—The general equation for radial stress ρ_R in a sphere is :

$$d/dR\ R^3\rho_R=R^3(A-2E\alpha T/(1-\sigma))$$

substituting the expression for T in this equation and integrating gives :

$$\rho_R=C_5-2tR_2/R/(k-1)+C_4R^3$$

The constants are evaluated from the boundary conditions, i.e. $\rho_R=0$ at each surface, to give :

$$\rho_R=2t\{(R_2^3/R^3-1)/(k^3-1)-(R_2/R-1)/(k-1)\}$$

The equilibrium condition for an element of the material can be derived from the stresses as indicated in Fig. 3 :

$$\rho_H=\rho_R\times\tfrac{1}{2}Rd\rho_R/dR$$

and this leads to the expression,

$$\rho_H=t\{(2-R_2/R)/(k-1)-(2+R_2^3/R^3)/(k^3-1)\}$$

At the inner surface

$$\rho_H=t\{1+(k^2+1)/(k^2+k+1)\}\ \text{compression} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

whilst at the outer surface

$$\rho_H=t\{1-(k^2+1)/(k^2+k+1)\}\ \text{tension} \quad . \quad (4)$$

It will be noticed that for a thin sphere ($k->1$) the hoop stresses at the two surfaces

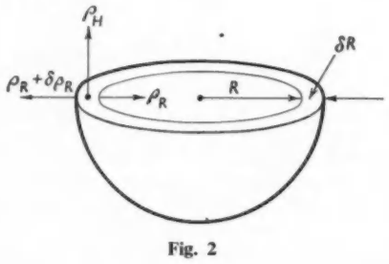


Fig. 2

are each equal to t ; as k increases the arithmetical difference between the stresses increases. In the limiting case of a very thick sphere the compressive stress at the inner surface tends to $2t$ and the stress falls away to zero at the outer surface.

Combined Stresses

If the two systems of thermal and pressure stresses are set up together, at the interior the thermal compressive stress and the tensile pressure stress tend to cancel whilst at the exterior both stresses are tensile and therefore additive. Unless one system of

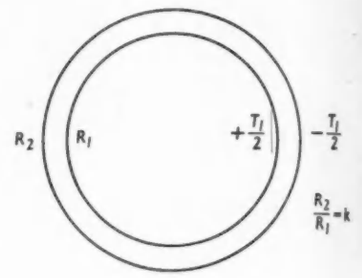


Fig. 3

stress is comparatively small the exterior will be the most highly stressed region, the hoop stress there having the value given by adding Equations (1) and (4) :

$$t\{1-(k^2-1)/(k^2+k+1)\}+\rho 1\tfrac{1}{2}/(k^3-1)$$

or

$$t(k-1)(k+2)/(k^3-1)+\rho 1\tfrac{1}{2}/(k^3-1)$$

This stress must be less than f, the safe stress in simple tension i.e.

$$t(k-1)(k+2)+1\tfrac{1}{2}\rho<f(k^3-1)$$

or

$$(k^3-1)-t/f\,(k-1)(k+2)-1\tfrac{1}{2}\rho/f>0. \quad (5)$$

and this is the required design formula.

Conclusion

The implications of the design formula (5) are seen most clearly if it is written out for various values of k :

$k=1{\cdot}1$
$0{\cdot}331-0{\cdot}31\ t/f-1{\cdot}5\rho/f>0$

$k=1{\cdot}2$
$0{\cdot}728-0{\cdot}64\ t/f-1{\cdot}5\rho/f>0$

$k=1{\cdot}3$
$1{\cdot}197-0{\cdot}99\ t/f-1{\cdot}5\rho/f>0$

$k=2$
$7-4\ t/f-1{\cdot}5\ \rho/f>0$

It is apparent that if a very thick-walled sphere could be constructed it could withstand very high thermal and pressure stresses if they were applied together ; either loading separately would cause yield at the interior.

The possibilities of a vessel of less extreme proportions, $k=1{\cdot}2$, are shown by the following figures.

If the temperature difference T_1 is 100 deg. Cent. and if f is 20 tons per square inch

$$t=\tfrac{1}{2}E\alpha T_1/(1-\sigma)$$
$$=(13{,}400\times 11\times 100)/2(1-0{\cdot}29)10^6$$
$$=10{\cdot}4\ \text{tons per square inch.}$$

With this value of t the internal pressure ρ may have a value of 5 tons per square inch without violating the design formula. It can be confirmed from Equations (2) and (3) that either loading can be safely applied separately.

Multiple Head Instrument for Aero-Dynamic Measurements

By R. E. MORRIS, M.Sc. A.M.I.Mech.E.*

In turbo-machinery research it is frequently necessary to measure total and static pressures, angle of flow and stream temperature at a large number of stations. Hitherto this has generally meant traversing with at least three separate instruments. If these four measurements could be obtained from a single combined instrument the time taken for a test could be substantially reduced and the accuracy improved. Such an instrument consisting of a wedge type static/yaw probe with a thermocouple contained in the base and a total head tube attached to its underside has been developed; it can be calibrated to give accurate readings up to sonic velocity. The development clearly illustrated the advantages of the wedge type instrument for both yaw and static pressure measurement over those previously used. It can be inserted through a ¾in diameter hole and has been used extensively in conjunction with an N.G.T.E. automatic yawing and remote control traversing gear and has given greatly increased speed of testing and accuracy. A simplified version which has no thermocouple and which can be inserted through a ¼in diameter hole has now replaced all other forms of total, static and yaw meter traversing instrument at the Napier Research Station.

In general, aerodynamic investigations involve measurements of total and static pressures, flow direction, and temperature.

In the case of investigations into turbo-machinery there are usually quite wide variations in flow conditions, and to obtain an accurate picture of the flow a very large number of readings is required at various stations within the flow passages. A typical example of the problem met with occurs in research on single stages of axial compressors. Here there is a very wide variation in conditions, and the variations in pressure and temperature are quite a high percentage of the pressure and temperature rises in the stage. It therefore becomes necessary not only to measure conditions to any one point with extreme accuracy, but also to take a very large number of readings in order to obtain an accurate mean. In the example quoted it is not uncommon to carry out a detailed traverse of two blade pitches, obtaining values of total and static pressures, flow directions, and temperatures at each of 200 stations, giving a total of 800 individual readings. This process may be carried out as many as ten times during a test. When this work commenced, three separate instruments were used, a combined total head/yawmeter, a needle static probe, and a total temperature thermocouple. As a result, to obtain a single traverse it was necessary to run for twelve to sixteen hours. Not only was it impossible to maintain constant conditions during so lengthy a period, but operator fatigue progressively reduced the accuracy of the results and the subsequent analysis involved lengthy corrections due to non-steady contitions.

Two approaches were adopted to remedy this. Obviously if all four measurements could be obtained from a single instrument the time taken could be reduced to approximately one third. Further improvements were obtained by operating the instrument by the N.G.T.E. remote control system, which also incorporates automatic self yawing. By these means the time taken for a traverse was reduced from 12 hours to 2 hours. This article deals with the development of the multiple reading instrument.

Quantities to be Measured

(*a*) *Total Pressure.*—This is normally one of the easiest measurements to make. The best method is by some form of tube pointing into the flow; such a tube is tolerant to up to 10 deg. misalignment with the flow in a uniform stream but in the type of flows encountered in turbo-machinery this tolerance seems to be about ±5 deg. These figures are for a square-cut nose tube which is slightly better by about 1 to 2 deg. additional tolerance compared with spherical or chamfered noses. The total pressure can also be measured by placing a tapping in the stagnation region of a body; one very common form of combined instrument is a three-hole cylindrical. In this device a cylindrical rod inserted normal to the stream has three holes spaced circumferentially 40 deg. apart, the two outside holes acting as a yawmeter. Either of these holes can be calibrated to give static pressure at zero yaw. At zero yaw the centre hole gives a total pressure. It has been the author's experience of this type of instrument that it is particularly liable to error when readings are being taken in flows which vary along its length, especially near boundaries, due to flows along the span of the instrument. This does not affect the total pressure to any great extent but leads to very large errors in static pressure and yaw.

(*b*) *Static Pressure.*—This is rather a more difficult measurement to make. In principle all that is required is a pressure tapping normal to the flow direction, but with a traversing instrument this static tapping has to be situated on some body and the readings can be affected by nose and stem effects. Extensive use has been made of the needle static instrument, which is a very much scaled down version of the larger standard instruments used in wind tunnels. These small units seldom read the true static pressure but can be calibrated and are useful for Mach numbers up to about 0·85, beyond which condition accurate readings are no longer possible.

As mentioned above, static pressure readings have been obtained by tappings on a cylindrical body situated at the point where static pressure theoretically exists. Unfortunately this point is also the position of maximum rate of change of pressure on the surface, and its position also varies with Reynolds Number. This variation can be quite appreciable since when traversing in small passages it is desirable to make the instrument stem itself as small as possible to avoid blockage and disturbance. In addition compressibility effects become noticeable at a Mach number of about 0·6 which is well inside the range encountered in gas turbine research.

In an attempt to overcome this, the tapping has been placed at the rear of the cylinder so that it reads wake pressure (approximately one dynamic head below free stream pressure). Such an instrument has reasonable tolerance to Reynolds Number variations and flow direction but it is extremely prone to errors when measurements are being taken near a boundary. It has also been suggested that static readings can be taken from one arm of a claw type yawmeter. The Author's experience is that this is very unsatisfactory, the readings appear extremely sensitive to misalignment in the flow direction and also to instrument damage. There is another family of instruments which consist in principle of immersing a flat plate with a sharp edge in the stream (so that there is no nose effect) and measuring the static pressure on the side of this body. One form of this, which has been used successfully and is the basis of the multiple head instrument to be described, consists of a narrow-angle wedge. By putting pressure tappings on both sides, not only is a pressure obtained which is close to the static stream pressure but it can also be used as a yawmeter. With very small instruments it is only seldom that the true static pressure is recorded; the desirable feature is that the pressure recorded should bear a suitable relationship to the true static pressure so that it can be calibrated. These

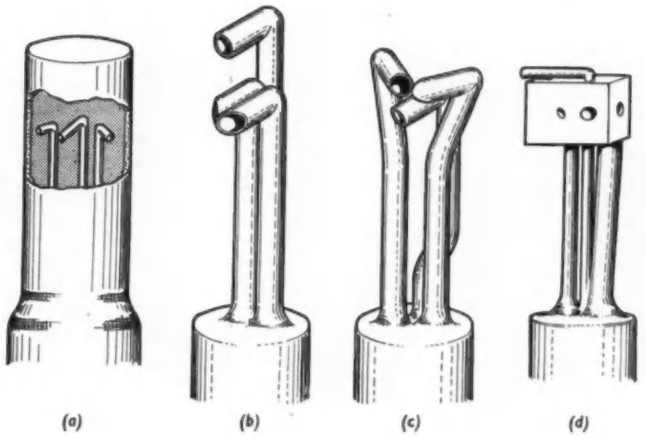


Fig. 1—Various types of probes for yaw measurement

* D. Napier and Son Ltd.

Technical Contributors Section (*continued*)

wedge type instruments can be calibrated against static pressure and are useful over the full subsonic region.

(*c*) *Flow Direction.*—In the general case a three-dimensional flow must be considered and instruments have been designed which are capable of being both yawed and pitched. It is a simple matter to yaw an instrument, as all that is normally necessary is to rotate the instrument about its own axis, but pitching involves a more complex mechanical construction. The instruments in any case tend to be rather more complicated, for instead of the two pressure readings common with yawmeters, four are customary. Suggestions have been made that direction-finding instruments of this type (either two-dimensional yawmeters or the more complex three-dimensional pitch and yawmeters) can be left fixed in position and the angle calibrated from the out-of-balance pressure readings. In the author's experience this has never been found to be satisfactory. Fortunately in many of the applications met with, particularly in axial turbo-machinery, the angular variations in flow take place very nearly in one plane only and some versions of a two-dimensional yawmeter is used. Fig 1 illustrates various types of probe for yaw measurement.

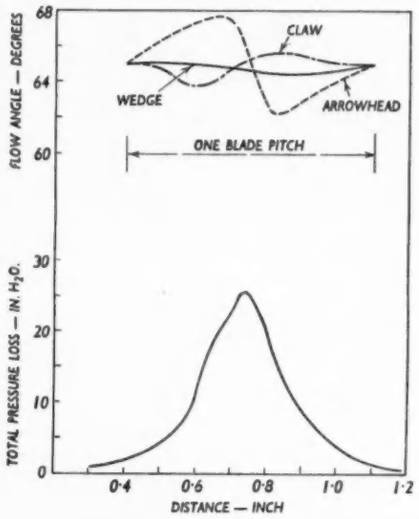


Fig. 2—Apparent flow angle variations obtained with claw wedge and arrowhead instruments

The cylindrical and wedge type yawmeters have already been described above. One of the most common forms of yawmeter is the claw type, consisting of two tubes bent so that when the instrument is aligned with the flow each tube makes an angle of 45 deg. to it. Such a construction is somewhat bulky and if the instrument is small it is also fragile. A more robust instrument is the arrowhead form where two tubes are brazed side by side, both in line with the flow but with their noses chamfered at 45 deg. Either of these instruments can readily be combined with a total-head tube provided that care is taken that flow disturbances caused by the total head tube do not affect the yaw tubes.

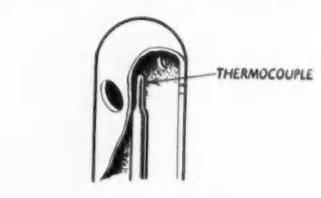


Fig 3—A typical temperature measuring instrument head

A disadvantage of these two instruments and of the cylindrical yawmeter is that there is a significant distance between the centres of the two measuring orifices, hence if such an instrument is used in a non-uniform stream it will indicate an out-of-balance reading so that when the instrument is turned to obtain zero differential pressure an angular error is obtained. This is a particular disadvantage in traversing through blade wakes and is especially serious in turbo-machinery where these blade wakes tend to occupy a full blade pitch so that there is no region of uniform flow where a constant angle reading is indicated. It is unfortunate that the arrowhead yawmeter, being based on pressures which are nearer to the total pressure of the stream, is more sensitive to this effect than claw type yawmeters which indicate nearer the static pressure. This is illustrated in Fig. 2. which shows the apparent variation in angle obtained with claw, arrowhead and wedge type instruments. This figure shows that the error is substantially reduced with the wedge type instrument where the flow is split into two portions at a knife edge so that variations in stream conditions have very little effect on the angular reading.

(*d*) *Temperature Measurement.*—The quantity most commonly measured in internal aerodynamics is the total temperature, that is the static temperature plus the dynamic temperature, and the figure of merit for a temperature indicator is its "recovery factor" i.e. the fraction of dynamic temperature recorded. The instruments designed to read total temperature are analogous to those designed to read total pressure, in that in principle the stream is brought to rest at some point on the instrument head and the stagnation temperature obtained. In practice, however, this has been found to be quite a difficult problem to solve. The majority of instruments currently in use bring the air almost to rest and then permit a small leak of air over the thermocouple junction in order to permit good heat transfer between the gas and the junction itself and thus avoid conduction errors. There are now many versions of instruments which have recovery factors of about 95 per cent ; Fig. 3 illustrates a typical example.

For the majority of overall performance calculations the total temperature is required, and it is obviously convenient if the instrument reads this quanitity or very nearly so. For very accurate work, however, as in the example of single-stage axial compressor tests, slightly different conditions obtain in that (*a*) an instrument with a recovery factor of 0·95 can no longer be considered as reading virtually total temperature, the 0·05 error being significant and (*b*) all the information is to hand for correcting an observed temperature to the true total value and the additional work involved is comparatively small compared with the rest of the analysis which will be carried out. In the application we are considering therefore, the requirement is that the readings should be very stable i.e. the recovery factor vs. Mach number curve should exhibit very little scatter and the recovery factor should preferably be constant or at least show very little variation.

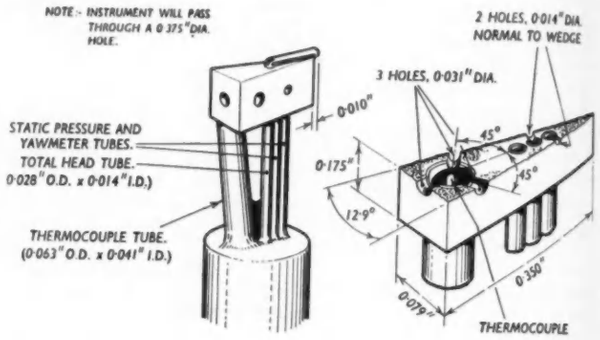


Fig. 4 — The instrument finally developed

Apart from the aerodynamic considerations the choice of temperature sensing element must also be considered. Since these instruments tend to be very small the element is nearly always a thermocouple. These have additional advantages in terms of robustness and ease of manufacture.

Combined Instruments.—One of the major problems of making a combined instrument is that of avoiding interference between one instrument and another. Consequently in order to meet the ideal of all readings being taken at the same point the instruments must be of geometrical forms which fit in

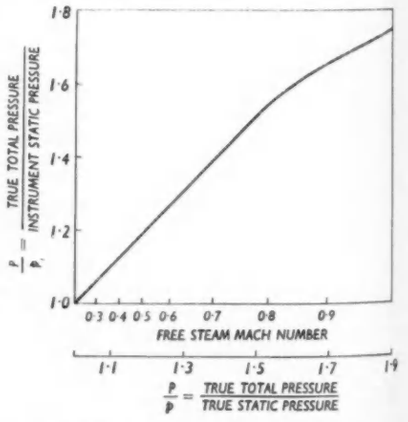


Fig. 5—Static pressure instrument calibration

well together and must be situated very close to each other, conditions which makes the first requirement, that of non-interference, difficult to meet. Our previous practice had been to combine total-head tubes with yawmeters, and to use separate instruments for static pressure and temperature measurement. In this investigation a number of combinations of the above types of instrument were manufactured and tested before the final version was obtained.

Final Version

Figs 1*d* and 4 show the instrument finally developed. It consists of a narrow wedge of angle 12·9 deg. with a tapping on each face to give static pressure and yaw angle. A total-head tube is situated below the wedge and a thermocouple is contained in the base

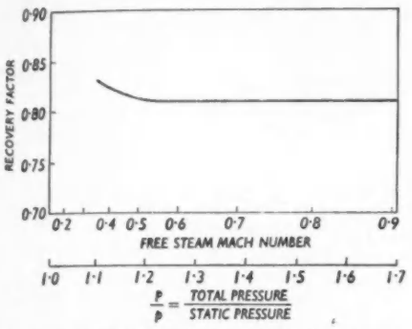


Fig. 6—Aerodynamic calibration of the thermocouple

of the wedge. Two tappings on either side of the wedge act as entry ports and a hole in the base of the wedge as a bleed.

This instrument is a fairly straightforward combination based on the wedge type of static pressure yawmeter. The total pressure tube has no influence on the static pressure readings but it has been found necessary to extend the nose of the total pressure tube 0·010in upstream of the leading edge of the wedge in order to avoid interference with total pressure readings. Fig. 5 shows a calibration of the instrument for static pressure and it will be seen that this is useful up to sonic velocity. Fig. 2 shows the apparent error in angle when traversing through a

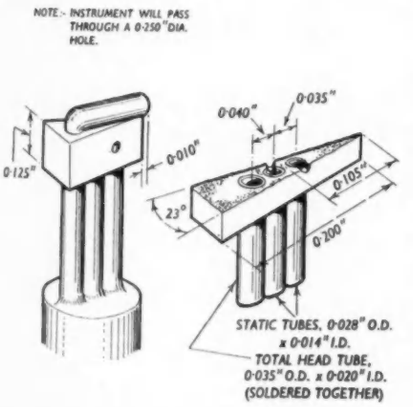


Fig. 7—The simplified pressure and yawmeter instrument for general aerodynamic work

non-uniform velocity field, the maximum error is 0·7 deg. compared with 1·2 deg. for a claw type yawmeter and 2·6 deg. for an arrowhead yawmeter. Fig 6 shows the aerodynamic calibration of the thermocouple, recovery factor being virtually constant at 0·81. This must, of course, be corrected in use but the information required for correction is readily to hand, and the consistency of the recovery factor is convenient in calculations. The instrument has been tested with a limited amount of pitch and will accept flows at ± 5 deg. of pitch with less than 0·8 per cent error in indicated velocity.

This instrument is quite robust. The only point that needs particular care is that the leading edge must be maintained as a sharp knife edge although the errors obtained when this is slightly damaged are not large. The claw type yawmeter on the other hand has been known to give completely misleading readings of static pressures with one arm bent, a form of damage which is often not visible to the eye. In an effort to overcome this, experiments have been carried out with radiused, chamfered, and flat-nosed wedges, but it has been found that these tend to give incorrect values of yaw angle and that this error varies quite significantly with Mach number.

Since development this instrument has been used extensively for research work on single compressor stages. A simplified version of the instrument has been developed for general aerodynamic work where temperature measurement is not required. This is illustrated in Fig. 7 and is similar in design to the instrument already described. It has been found possible to increase the wedge angle to 23 deg. and thus enable a larger bore total pressure tube to be fitted, reducing the response time of the instrument. The thermocouple has been omitted. The complete instrument can be inserted through a $\frac{1}{4}$in diameter hole and has now entirely superseded other types of combined pressure and yawmeters in D. Napier and Son, Ltd.

Acknowledgement

The work described in this article was carried out at the Napier Research Station, Liverpool, and the author's thanks are due to D. Napier and Son, Ltd., for permission to publish this article. The opinions expressed are the author's own.

Differential Transformer for Amplitude Control of a Vibrating System

By H. B. DALE B.Sc.(Eng.) (Hons.) A.M.I.Mech.E. A.M.I.Prod.E.*

An electromagnetic control system, based on signals from a differential transformer connected to the specimen under test, has been developed for investigating the fatigue failure of electrical resistance strain gauges.

THE device described in this article has been in the process of development for some time. Initially some *ad hoc* testing of high-tensile wire was urgently required for a local manufacturer. The wire to be tested was 16 S.W.G., 16in long, subjected to rapid vibration whilst fixed as a cantilever, the amplitude of vibration being $\pm\frac{1}{4}$in. Some failures had occurred in service. If a mock-up of the mechanical set-up had been used, the time taken for the necessary testing would have been too long and for various reasons the speed could not be significantly increased.

It was decided to try an electromagnetic system of vibration, the vibration being set up by means of a soft-iron core mounted between two electromagnets fed by an a.c. supply, the amplitude being governed by the power input. Difficulty was experienced in controlling the amplitude, as variations of the natural frequency arose, probably due to work hardening of the material. The tests were a limited success.

The project was in abeyance for some time and then the need arose for further vibration testing of a different nature but requiring close control of the amplitude of vibration of the specimen (not wire in this case).

After some exploratory work using electrical resistance strain gauges as a control of the amplitude, it was found that breakdown of the strain gauges was occurring, mainly at their lead junctions. These failures were occurring at about 7×10^5 reversals, at 0·1 per cent strain. Some modification of the gauges was tried, the most successful being the introduction of a curl in the strain gauge wire just before the lead junction. These modifications served to raise the limit of fatigue failure of the gauges by some 10 to 15 per cent.

After further consideration it was decided to develop an electromagnetic system of control of frequency and amplitude of vibration. This system uses a coil vibrating in a magnetic field together with a control circuit based on the differential transformer. The basic driving unit consists of a permanent magnet (from a moving coil loudspeaker) with a coil of seventy-five turns of 26 S.W.G. enamelled wire, fed by a variable frequency a.c. supply, moving in its field. The supply to the coil is controlled by the output from a

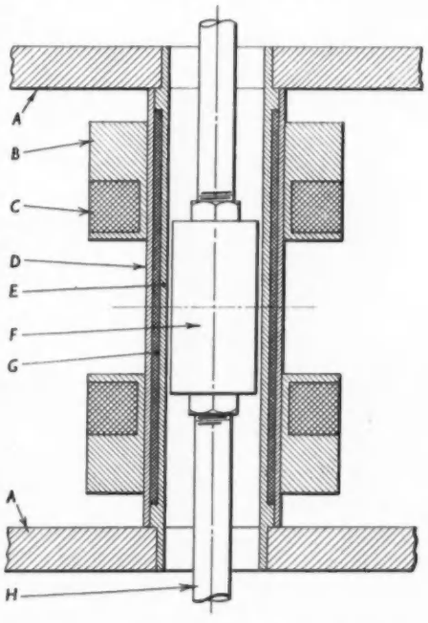


Fig. 1—Construction of differential transformer

* Senior Lecturer in Mechanical Engineering, Letchworth College of Technology.

Technical Contributors Section (*continued*)

differential transformer, the moving component of which is connected to the vibrating moving coil, and to the test specimen.

The differential transformer (Fig. 1), which is fitted between the driving coil and the vibrating specimen, consists of a ferrite slug *F* fixed to a 6 B.A. rod *H* by means of two nuts, one at either end of the slug. The two ends of the 6 B.A. rod are centralised by means of flat "Tufnol" springs. The lower end is then linked to the driving coil, the upper end being linked by means of piano wire to the specimen, which is mounted as a cantilever.

The joint between the piano wire and the specimen consists of a polyetrafluorethylene ball working in a spherical seating at the end of the cantilever specimen. The differential transformer coils *C* are mounted on a " Tufnol " sleeve *D*. Each coil consists of 250 turns of 40 S.W.G. enamelled wire, matched for impedance, wound in a recess in a " Tufnol " bush *B*. These bushes are a tight fit on the " Tufnol " sleeve so that their positions in relation to the ferrite slugs may be adjusted.

The primary winding *G*, of fifty turns of 32 S.W.G. enamelled wire, is wound round a recess in a long " Tufnol " bush *E*, stepped at each end and located between two plates which hold the assembly rigid by means of long bolts passing through them, and attached to the permanent magnet.

The displacement of the ferrite slug causes a variation in voltage across the secondary coils. This variation in voltage is used to control the power supplied to the vibrating coil driving the specimen. As shown schematically in Fig. 2, the primary of the differential

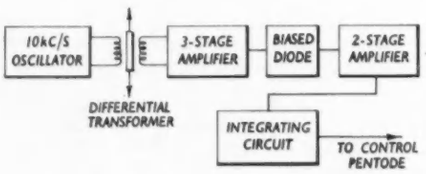


Fig. 2—Arrangement of control circuits

transformer is fed by a 10 kc/s oscillator. The output from the differential transformer is fed, via a three-stage amplifier, to a biased diode. The bias is obtained from a stabilised source and is adjustable by means of a potentiometer. The setting of the potentiometer fixes the value of the input signal required to cause the diode to conduct. The value of the input signal to the amplifier is determined by the position of the ferrite slug. No output is obtained from the diode until the movement of the specimen exceeds a certain amount, the amount being predetermined by the setting of the bias voltage on the diode.

The output from the diode is then fed to a two-stage amplifier and integrator and thence to the control valve, a short suppressor based pentode. The control voltage is fed to the suppressor grid of the pentode, thus controlling the valve output. This

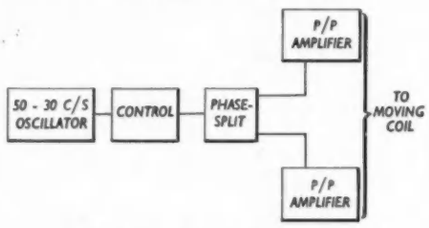


Fig. 3—Drive to moving coil vibrator

output is fed to a phase splitting circuit and then via a pair of push-pull amplifiers to the driving coil (Fig. 3). The output to the coil is about 10W.

In the present application the amplitude of the specimen is measured by the output from an electrical strain gauge mounted on the specimen. This method does give a quick and easy method of checking the amplitude of vibration whilst in operation. Static calibration is straightforward as the output from the gauge is measured on an oscilloscope, the displacement of the gauge being measured physically. The maximum displacement from the mean position was 0·1in.

The frequency of vibration was checked by means of a double-beam oscilloscope, one beam being fed by the output from the variable frequency oscillator and the other fed by a standard frequency oscillator. It was found that after hunting for the first few cycles there was no measurable deviation from the desired deflection even after prolonged periods of testing, unless the frequency was close to the natural frequency of the system, when some drift was found to occur.

Whilst this rig (shown complete in Fig. 4) is used at the present to investigate the fatigue failure of the electrical resistance strain gauges, it should be useful in any fatigue testing of small components subjected to alternating stress.

My thanks are due to the Governors and the Principal of the Letchworth College of Technology for permission to publish this article. The work in connection with this device was carried out at the College, the apparatus being manufactured in the laboratory with the assistance of the senior laboratory technician, Mr. J. Pike.

Fig. 4 — Rig for fatigue testing of small components

THE ENGINEER

REVIEW OF BOOKS

AUGUST, 1961

Water Power Development

EMIL MOSONYI. Translated from Hungarian

Publishing House of the Hungarian Academy of Sciences, Budapest, V, Alktomany, U.21
Price 120*s.*

THIS is the second volume of the English translation of the monumental treatise on on water power developments originally published by the author in Hungarian. The Hungarian version was essentially a university textbook, and as such was mainly intended to cover the local conditions prevailing in Hungary. It was, therefore, chiefly concerned with low-head installations, such as are often met with in that country.

Since, however, the English edition is written for a much wider circle of international readers, greater attention is now devoted to high-head developments, including such modern developments as surge-tanks, underground power-stations, pumped-storage schemes, and the like. All this has contributed to a radical change in the scope of the work. Whilst the original Hungarian edition consisted of two volumes only, the new English edition comprises three volumes, as follows : first volume, general principles and low-head developments ; second volume, high-head, midget and pumped-storage developments ; third volume (in preparation), river barrages, valley dams, metal equipment and economic aspects.

Volume two goes beyond the usual limits of undergraduate study, and thus embraces all the requirements of the actual designer's office. In fact, the information it contains is designed on so wide a scale, that one should not hesitate in classifying the book as an indispensable attribute of a modern water-power projects bureau. It is almost impossible to give in a necessarily-brief review, a complete list of all the subjects dealt with in this book. The following list must, therefore, be considered as containing only those of the items, which particularly drew our attention.

Starting with the upper end of the installation, the author begins with a full account of the design principles of the canal intake, inclusive of the settling basin, &c. (formulas of Sudry, Velikanov and others). Next comes the power-canal, the headpond, the tunnel intake, the tunnel itself and the stresses occurring in its lining.

In this connection we recollect how, about fifteen years ago, we had the opportunity of visiting—in company with its builder and designer, M. Juillard—the power station Innertkirchen in Switzerland. At that time our attention was particularly centred on the steel-lined tunnel, which was designed by M. Juillard taking into account the relative elasticities of steel and rock. By these means much load was transferred to the rock and considerable saving was possible in the weight of the steel. At the time, this was a material achievement, but now we find all this theory fully explained in Mr. Mosonyi's book, and of course, the Innertkirchen tunnel duly mentioned.

We next come to the problem of the surge tank. Some 120 pages of the book are devoted to this subject. Water surface oscillations are computed analytically and by graphical means. Names of Eydoux, Jaeger, Prasil, Calame and Gaden, and so many others appear on the pages of the book, in this section.

The design of the various types of penstock is fully explained by means of formulas and nomograms (Ferrand). The valves and valve-chambers are illustrated by numerous examples. The penstock-hydraulics, inclusive of the water-hammer and relief-valves, is dealt with in detail. The structural analysis, inclusive of the anchorages, forms another part of this section, which is concluded by a chapter on the economical choice of the penstock diameter.

The chapter on power stations follows. It begins with the general arrangement of the power house. Next comes the section on underground power stations, which are particularly well described. Here again, the methods for determining the elasticity of the rock (in particular, the geophysical methods depending on the celerity of the seismic wave) are well discussed, because of the important part they play in the calculation of resistance of the underground structure of the machine hall. Various layouts are illustrated by examples. Unlined machine halls are also referred to. Ventilation problems are fully explained. Instances of semi-underground layouts are given. The arrangement of various types of tunnels leading to underground stations is carefully gone into. Tail-water conduits of various description are also produced.

The concentrated-fall arrangements form the subject of the next section ; that is to say, these are the power-houses built in immediate vicinity of the dam. They may either be high-head, or medium-head developments, and are extremely numerous in all parts of the world. A French application of the type (due to the late A. Coyne, whose name, however, is not mentioned) which consists in letting the water falling from the crest of the dam, to slide over an impermeable inclined roof, built over the power house, is mentioned ; but the instances quoted are Czechoslovakian (e.g., Slapy dam) rather than French (although L'Aigle dam is given as an illustration, its principle is not explicitly described). Attention is drawn to the specific features of the penstocks located inside the dams, such as " hedgehog spine anchorages," and various types of air-valves.

Hydraulic and electrical equipment are described in the next chapter. The turbines here considered are the slow-speed Francis turbine and the Pelton wheel. The range of the specific speeds covered by these two types is from 4 to 200 r.p.m. (metric), corresponding to the " high-head " developments considered in the volume. The amount of information supplied on this subject, is very wide, substantial and to-the-point. The number of empirical and semi-empirical rules required for design purposes is ample. Many diagrams are included. The erosion factor is fully considered. Francis turbine and Pelton wheel efficiency diagrams of the hill type are produced. The constructional details of the Francis turbines are illustrated by a plentiful supply of examples. The diagram giving the specific weight of the turbine is a useful addition. The information for the preliminary layout of the scroll-casing of Francis turbine will be found useful. The Pelton wheel design is equally well illustrated. The design of the generator completes this chapter.

In the next chapter the author describes what he calls the " Midget Power Plants," which we might sooner classify as

REVIEW OF BOOKS *(Continued)*

"water-wheels," rather than "turbines." They include the overshot wheel, the undershot wheel, the bucket wheel and so on. For us this is the least interesting part of the volume, though midget-power-plants with turbines, are also considered.

It remains now to describe the last, but by no means the least part of the book : the pumped-power developments, which become every year more important and the scope of which is constantly growing. The author begins first with the description of the purposes and general layout of such schemes, which are illustrated by references to many actually executed projects, for instance the Ffestiniog, the Vianden, the Geestacht, the Lünersee, the Kapran, and so many others. The various parts forming such a scheme are then analysed individually, such as the upper and lower basins (if any), the canals and tunnels, the power houses, intake and outlet works of various kinds. Much attention is devoted to assembling on one single shaft the turbine, the pump, and the generator capable of working as a prime mover. The details of such mechanical equipments are dealt with in a separate section, including multistage storage pumps, &c. The relative advantages of various kinds of shaft-couplings in such arrangements are considered, as well as the reversible hydraulic machinery. The efficiency of this class of power station, with various types of machinery, completes the exposition.

The reader will observe that this is a welcome addition to the library of any engineer interested in water power projects and similar problems.

Design of TVA Projects

Technical Report No. 24. Vol. 3. " Mechanical Design of Hydro Plants."

Publisher : U.S. Government Printing Office, Washington, D.C. *Price 3.75 dollars*

THE Tennessee Valley Authority multi-purpose projects are internationally known and their Reports frequently consulted by those seeking information for similar developments. Technical Report No. 24, *Design of TVA Projects*, codifies experience on individual schemes ; Vol. 1 on " Civil and Structural Design " and Vol. 2 on " Electrical Design " were released in 1952 and 1953 respectively. Vol. 3 is concerned with " Mechanical Design " and the specialised fields involved in major hydro-electric stations.

Since 1935 TVA has constructed twenty-three power stations and acquired six, and operationally its system embraces another fifteen owned by ALCOA (426MW) and five (565MW) by the U.S. Corps of Engineers, aggregating 3727MW excluding thermal plants built to meet the growing demand following harnessing of hydro-electric resources and, *inter alia*, flood control and navigation channel improvement upstream of Paducah (Kentucky). Chapter 1 touches on these questions in introducing the specialised material which follows.

The river basin characteristics allow the schemes to be classified into main river, tributary and diversion types of which there are nine with a head range of 36ft to 65ft incorporating navigation locks, eight within 90ft to 330ft and six within 180ft to 360ft respectively. Typical sketches demonstrate that the conditions within these classifications has permitted standardisation leading to design, constructional and operational economies.

The book appears to have two staff objectives, rather than the general reader, in mind, namely :

(i) A reference for the individual schemes (Chapter 3).

(ii) A code of practice (Chapters 4–17) and specifications (Appendices A–D) for mechanical plant and ancillary services.

Each scheme is treated uniformly and broadly introduces the civil and electrical works and describes the associated mechanical equipment in some detail. It is evident that high design and construction standards are demanded throughout.

The text and drawings embrace the main features, including outdoor, semi-outdoor and indoor stations with plant limited to vertical propeller, Kaplan and Francis turbines. Remote control facilities have been incorporated on forty-seven units in seventeen plants, four of which are operated by carrier current and the remainder by wired circuits.

Kaplan turbines in the main river stations such as Kentucky, Watts Bar and Fort Loudon, to quote recent examples, have an output around 45,000 h.p. at about 40ft to 50ft head. Francis units in tributary stations like Douglas, Boone and Cherokee are about 35,000 h.p. to 40,000 h.p. at 80ft to 100ft head with the diversion types, usually having differential or restricted orifice surge chambers and butterfly valves such as Fontana and Apalachia are in the 40,000 h.p. to 50,000 h.p. range at about 350ft head. Wide head variations seem to be accepted for Francis turbines where high head Kaplans might be justified.

The sections devoted to design, selection, erection and testing of propeller, Kaplan and Francis turbines and valves, reflect the American viewpoint and experience on specific speed, hydraulic thrust, cavitation settings and margins, spiral casing and draft tube dimensions. Governor information is mainly concentrated on one standardised design, but nevertheless the layouts and accompanying specifications contain useful data on speed regulation, sensitivity and dead time, pump, receiver and sump capacities, auxiliary equipment and operating controls.

Some standards of cavitation damage are noted :

	Francis D^2 Boone	Kaplan $1{\cdot}5D^2$ Fort Patrick Henry
Machine type		
Permissible weight loss, W lb		
Station		
Runner discharge diameter, D feet	14·50	13·25
Speed, r.p.m.	100	138·5
Head range, ft	65–123	58–75
Output, h.p.	34,500 at 90ft	25,000 at 61ft
Rated head, ft	110	67
Specific speed	67	129
Plant, Sigma	0·35	0·78
Submergence, normal, ft	+4·0	−7·0
Cavitation limitations (one year) :		
At outputs below minimum, hours	800	800
At outputs above maximum, hours	50	50
Permissible damage area, square inches	4·0	4·0
Permissible damage depth, inch	0·1875	0·1875
Excessive Cavitation :		
Runner, cubic inches	500	300
Throat ring, cubic inches	—	200
Weight (estimated), lb	170	140
Weight (formula), lb	210	263
Weight (ratio)	1·24	1·88

Runners are of cast steel with 0·125in stainless welding overlay, based on model test observations, with cast or rolled steel discharge rings on which some damage has been experienced.

Electrically operated butterfly valves with long closing times are typical of U.S. practice.

Station	Head, ft	Valve dia., ft	Motor, h.p.	Leakage, U.S. g.p.m.	Closing time, secs.
Ocoee No. 3	175	12	25	4	60
Apalachia	222	12	20	300	300
Watauga	325	11	35	13	360
South Holston	150	15	10	65	300

An interesting confirmation of European experience is the replacement, due to trouble with abrasives in the water, of submerged water lubricated bearings, by greased types with the automatic compressor also serving the guide apparatus. Other turbine features worth noting are the use of :

(i) Equipment permitting changeover to synchronous condenser operation in about one minute.

(ii) Roller bearings for Kaplan turbine blades.

(iii) Low-temperature flame stress relieving for field welding.

(iv) Chromium plating, automatic solenoid hydraulic locks, balancing at 30 per cent opening and adjustable timing on guide vanes and regulating mechanisms.

(v) Model tests to fix generally acceptable spiral casing and draft tube profiles where structural stability required immediate construction for future units.

Station drainage and draft tube/spiral casing de-watering and filling systems, except for ejector installations, follow conventional practice.

For Kaplans with concrete and Francis turbines with steel spirals, the text and diagrams specify the procedures for placing and locating embedded parts and for aligning the internal components and coupling connections with shaft throw and runout limits. Most turbine efficiencies seem to be based on correlated model and index tests using Winter Kennedy differential pressure equipment, but details are given for the equipment, layout and results of Gibson tests at Norris on two 66,000 h.p., 165ft head Francis units and the unsuccessful attempt to use the Allen salt velocity method for the Hiwassee pump-turbine in the pumping phase due to spiral flow entering the measuring section. Typical test reports include index tests for setting Kaplan cams, flow meter calibration and

overall efficiency with derived unit speed, and output topographical diagrams which are used for reservoir operation. These only seem to include cavitation limits indirectly. Other test reports cover runaway speed, shaft deflections, servomotor oil pressures and governor performance on load rejection using high-speed recording charts for gate movement, speed and other characteristics.

While Vol. 3 is a guide for comparable schemes and illustrates current American public utility and manufacturing practices, there are only occasional references to operating difficulties, and further details including maintenance costs and availability figures for the seventy-seven machines (2401MW) would have been enlightening. The trend of unit costs for turbines and generators between 1935 and 1958 is discernible in the figures quoted and analysis might prove interesting in view of recent U.S. investigations concerning marketing practices and for comparison with European data.

The specialist engineer, unfamiliar with hydro-electric plant requirements, will find valuable data in the text, drawings and specifications for automatic lifts, compressed air systems for plant and station services as well as other items which are seldom mentioned in textbooks but are nevertheless essential for station operation.

Ancillary services are not only related to the machines they serve but also to the installation, operating and climatic conditions. For example, auxiliary gasoline engine driven generators (35–400kVA) were installed at eleven stations to cater for the simultaneous loss of power generation and transmission at high flood periods. These are housed within the stations, necessitating fire-proof construction, CO_2 flooding, firedoors, ventilation and outside fuel tanks buried in fill. Fire protection has received much attention as regards equipment hazards, structural considerations and training of personnel. Water and classified CO_2 systems based on total flooding, local application or initial plus delayed discharge are used according to the risk, but curiously no reference is made to leakage detection (apart from weighing of cylinders), oxygen masks or purging after gas release. Water spray and fog systems are installed for transformers and portable extinguishers are distributed throughout the stations.

Since much of the plant, particularly in the main river stations, is below water level and because of climatic conditions, air ducted and radiant space heating, ventilation with centralised fan systems for heat, moisture, air and odour removal, as well as mechanical refrigeration for air conditioning, are necessary. Some design data and specifications for fans, refrigerant compressors, auxiliary equipment and accessories are provided.

Handling facilities for medium and heavy lubricants, operating and insulating oils for generating plant, transformers and switchgear insulation, with stated characteristics, incorporate provisions for filling, circulation, removal and purification via pumps, pipework and dirty and clean oil tanks.

Raw water for machine, station, fire and miscellaneous services, treated water and sanitary systems conform to customary hydro-electric practice, although the latter are governed by local conditions and/or state health requirements.

Importance is rightly attached to all pipework systems. Basic flow diagrams with uniform nomenclature showing all machinery, valves and controls serve as a functional guide for detailers, erection and operating personnel and for procurement of materials. Data on pipes, fittings, valves and accessories are included.

Each station has workshop equipment for normal maintenance for which details, space requirements and layouts are given. For special work the extensive generation and transmission system justified a central repair shop at Wilson Reservation which, apart from normal workshop operations, can undertake such specialised tasks as thrust bearing machining, transformer rewinding and oil reconditioning.

Miscellaneous projects illustrate the diversity of tasks consequent upon river basin development where mechanical engineers become involved with backwater protection, malaria control and river terminal facilities for increased traffic on the 650 mile navigable channel.

Unusual information, notably on design production costs, procurement, progress and construction scheduling and operating instructions for ancillary services is included.

While Vol. 3 is not a "do it yourself treatise" it is an inexpensive mine of well indexed information which the expert and uninformed should appreciate, and an appropriate companion to Vols. 1 and 2 which must be consulted for information on cranes, spillway and intake gates and generators.

Technical Report No. 24 and visits to some TVA plants confirm the impression of more liberal and meticulous design than in comparable European stations and that similar publications by other undertakings would make for improved station design, construction, operation and performance.

Nigel Gresley, Locomotive Engineer

F. A. S. BROWN

Publishers: Ian Allen, Ltd., Craven House, Hampton Court, Surrey. *Price* 35*s.*

IT is an impressive commentary upon the hold railways in general, and the steam locomotive in particular, continue to exercise upon a considerable section of the public, that despite the increasingly rapid superseding of steam the literature on the subject is steadily increasing. The more enterprising and learned of the many amateur enthusiasts sooner or later seem to commit the results of their hobby-studies to paper, and to-day in addition to many magazine articles the number of finely produced fully-bound books is steadily growing. Some, while having no pretensions to any literary style or make-up, are very valuable works of reference for the specialist amateur. Some others are indefensibly slipshod and unreliable, while a further group, while giving ample evidence of painstaking study and care in composition, leaves one with the impression that the author is at times a little out of his depth.

The subject of this present review tends to fall into the last-mentioned category. The work of Sir Nigel Gresley as a locomotive engineering designer has been very fully documented in the technical press, in a book published some fifteen years ago, and by contributions to the proceedings of the Institutions of Mechanical and Locomotive Engineers by both Gresley himself and a number of his senior assistants. The present book can best be described as a symposium of the previous published works on the subject, plus a number of items which could be described as "background music" to the main events. So far as it goes the book is a faithful record of what was designed and what was built—not all that was designed being built. It is, however, when the author ventures away from the factual chronicling of the details of engine construction and attempts a wider interpretation that he is less successful, and in some cases inaccurate. The factual detail also is so comprehensive, *in its very detail*, that there are times when it is difficult to see the wood for the trees.

One feels that in producing so beautiful and handsome a volume an opportunity has been lost of portraying Sir Nigel's work as a locomotive engineer in its broadest terms. His work was carried on at a time of serious financial difficulty. He had no mandate from his Board to indulge in a vast policy of "scrap and build," such as was given to his great contemporary (still vigorously at work in a different sphere) Sir William Stanier on the L.M.S.R. In the aggregate the total number of new locomotives built for the L.N.E.R. in Gresley's time was relatively small, and it was a matter not only of policy but necessity to maintain in good order the first-line locomotives of the constituent companies. Yet one feels that even if a great programme of new construction had been authorised Gresley himself would have had little use for standardisation as between the practices of the various works. An example of this is to be seen in the building of the "N7" class 0–6–2 suburban tank engine—a design based upon former Great Eastern practice and having a Belpaire firebox. At one stage an order to build a batch of these engines was given to the ex-Great Northern works at Doncaster. Now the Doncaster plant had never previously built a locomotive with a Belpaire firebox, and specially for this order the drawing-office at the works set to work to design a new boiler for the "N7" class, with a round-topped firebox, so that tradition could continue.

The author describes all the various types of locomotives with three cylinders that came to incorporate the well-known Gresley derived motion for the centre cylinder, eliminating the need for a third set of valve gear. While it can be said that this gear proved successful on the larger express and mixed traffic locomotives of the 2–6–2, 4–6–2, and 2–8–2 types which would have needed more than two cylinders in any case to provide the requisite tractive power, its use on suburban tank engines, on heavy mineral engines, and particularly upon the small 2–6–2 "Bantam Cock," which but for Gresley's untimely death might have been built extensively for light mixed traffic duties, was more questionable. Mr. Brown's book, however, is a chronicle, not an appraisal, and therefore it contains no over-riding review of Sir Nigel's work, now to be seen twenty years after his death.

In reviewing a book that has been so obviously a labour of love on the part of its author it would be graceless to catalogue errors, most of which occur in the "background music" rather than in the main chronicle. But one important item must be mentioned in connection with the world speed record of the "A4" "Pacific" engine "Mallard" in June, 1938. Mr. Brown states that on this historic trip Sir Nigel Gresley rode in the dynamometer car. This is not so.

REVIEW OF BOOKS *(Continued)*

The real purpose of that Sunday outing had to be kept something of a secret. The speed limit was then 90 m.p.h. and any excess in the regular working of the streamlined trains earned for the driver concerned a reprimand from the running superintendent. That special run came as one of a series of Sunday outings on which a number of experiments were made with modified forms of brake equipment, and on the record run a number of senior engineers and test assistants from the Westinghouse Brake and Signal Company were on the train, and actually measured the effects of a light brake application at 120 m.ph.

Despite its limitations this book is an enjoyable one to peruse in its recollections of a great period in locomotive history—in fact we were almost tempted to write a "heroic" period. One can have nothing but praise for the way the book has been produced, the dust jacket being particularly effective. On the other hand it is rather a pity that the great majority of the illustrations are from the drawing-office record "portraits" of the locomotives and carriages concerned, which means that not only are they familiar, but they are lifeless as well. To those "who worship at the shrine of the steam locomotive"—to quote a memorable phrase of the late Loughnan Pendred—one of its greatest charms is the spectacle it makes when in full action, shooting forth volumes of exhaust steam and smoke. This tribute to Gresley, himself one of the most ardent supporters of steam against all comers, would have been improved by the inclusion of a higher proportion of action photographs among the illustrations.

Construction of Gothic Cathedrals

JOHN FITCHEN — A Study of Mediaeval Vault Erection.

Publishers: The Oxford University Press, Amen House, Warwick Square, London, E.C.4.

Price 63s.

THERE is a vast literature on the history of mediaeval architecture, but little indeed on the methods actually employed by mediaeval builders. To erect one of the lofty cathedrals of Northern France clearly demanded marked ability and experience both in design and in site organisation. To raise its lofty superstructure with manpower only, and at an economical cost, called for great skill in devising, erecting and striking centring, scaffolding and shoring. Accounts of the money paid for labour, materials and equipment used in some famous buildings have fortunately been preserved; but no one with a craftsman's knowledge and experience ever recorded how the falsework actually used was prepared and erected. Literary descriptions of buildings by churchmen and travellers provide occasional glimpses, but such authors are notoriously vague and often misleading on practical matters. Actual details of the finished work, particularly when opened up for repairs or by war damage, can reveal to the discerning eye that certain procedures might and that others could not have been followed in the erection of a particular building. The author has made excellent use of such evidence, and of the literature of the subject, particularly of the two classic studies by Viollet-le-duc (an architect) and Auguste Choisy (an engineer).

The work even of these masters, however, left inevitable gaps and was sometimes frankly conjectural. To carry the subject further required wide scholarship, facility in several languages, a knowledge of structural science, and, even more, sound structural sense and that disciplined imagination that is the essence of all research and detective work. Fortunately Professor John Fitchen, of Colgate University, Hamilton, New York, has brought to the study of vaulted Gothic construction just these qualities, and a grant from the American Institute of Architects has made it possible to produce his work in worthy form.

Professor Fitchen's story, briefly, is this. The Romanesque builders, following the example of the Romans, made considerable use of interesecting barrel vaulting. For undercroft construction the centering could be, and presumably was, of earth. For a lofty vault, however, woodwork was indispensable, even if the final curved surface was formed by spreading earth over rough boards and facing it with plaster. Boards at that time were nearly always riven, not sawn, and dressed by axe or adze. The formwork for a completely sheeted barrel vault was extravagant in material and labour. Procedure was much simplified by breaking up a length of vaulting into a series of equal bays with an arch rib at each division. With diagonal ribs as well as transverse it became possible to treat the ribs as the main structure and to lighten the intervening webs. Only the ribs needed support from below; the web falsework could be carried by the rib centres. This was clearly an important matter when vaulting was undertaken at heights exceeding 100ft from the ground floor. The outer walls of Gothic cathedrals were, we are told, carried up to their full height, steadied by their flying buttresses (which need exert no horizontal thrust while their centres remain in place) and surmounted by the wooden roof structure before the stone vaulting was built. The tie-beams of the roof then provided support for a working platform on which windlasses driven by hand or by treadmill could be mounted to hoist half-centres fabricated on the ground floor. The heads of the centres were firmly keyed together, and their feet wedged up on staging of which both the positive supports and the raking shores, all of unwrought poles, took their bearing on the masonry at triforium gallery level and left the body of the church below that level clear of any obstruction by scaffolding. Scaffold decking would normally be of hurdles. With the masonry ribs in place on their centres, the thin webbing masonry between them could either be erected on lagging members, or in some types of vaulting by ingenious means that avoided the use of any temporary formwork at all between the ribs.

The text is illustrated by many excellent line drawings and a few photographs. Comments and references are collected as end notes; lengthier references and quotations are given in sixteen appendices. These notes and appendices are a mine of information for the student. The book also contains a glossary, twenty pages of bibliography and indexes under Author, Subject, Place and Building.

With reconstructions based in part, inevitably, on inspired conjecture it is always possible to cavil. If a challenge to the author must be made, it would be on his suggestion that the multiple or crocket wedge may have been used to support bridge centres in antiquity. It was not used in eighteenth century France when and where some of the most advanced masonry bridge construction of all time was in full swing. Its first recorded use was by Robert Mylne at Blackfriars Bridge, London, in 1760; that use has been thought to be original. However that may be, the general picture presented by this enthralling book is a timely contribution to our knowledge of an important stage in the development of structural practice, presented in such a way as both to carry conviction and to arouse the reader's admiration for a difficult task well executed.

THE MANAGER AND THE ORGANIZATION

Eric Moonman

Publishers: Tavistock Publications

Price 21s.

IT is rather arresting to read in an introduction by Mr. William H. Whyte to an interesting book that "the art of management... cannot be conveyed," for the question is immediately raised—if so why write on the subject? While the foregoing contention may be partially allowed, much will undoubtedly be gained by a study of the experiences of others. Mr. Moonman rightly points out that the higher an official reaches in an organisation, the less he is occupied with technicalities. It is doubtful, however, whether such a man could be a real success unless he had a practical background which must inevitably tend to influence his decisions. Managers will find it profitable to read this book if only because it points the finger to many places where the average manager fails. For instance, how many managers are really capable of writing a good and condensed report; how many can properly interview prospective employees?

The book is divided into two main parts: the first dealing with the manager himself, and the second with the organisation. A number of suggestive exercises, based on the subject matter of the different chapters, will cause many to realise how much they have still to learn: at the same time it is suggested that all of the answers to the questions raised will not be found in the book under review. A useful section is devoted to reference to other authors and their works, which can be read in conjunction with the different

chapters. The value of good communication between different individuals and branches in an organisation is stressed, while it is mentioned that attention is often not sufficiently directed to an individual's power to express himself.

The author does not anticipate his manager being a superman, but he does expect him to have considerably more in his favour than being just a good technician. It is essential that he can faithfully carry out instructions, and is not averse from delegating responsibility to his subordinates. The man who aspires to be indispensable is a danger to the organisation, whereas, strange though it may appear, when the temporary absence of an official is not even noticed and the wheels continue to run smoothly, admittedly not indefinitely, that official is probably a success. The idea of "muddling through" is anathema to the efficient manager. Too often prejudice creeps in unawares, but yet its harmful influence is not realised at once, and as Mr. Moonman says "the idea that the worker is lazy, that employers are exploiters, out for their own gain, that shop stewards are Communists, and a whole series of similar irrationalities and *non-sequiturs* frequently bedevil industrial relations."

The value of style and simplicity in expression is of great importance, and it is a pity that certain Government departments find it necessary to resort to what the author somewhat scathingly but aptly describes as "official jargon," a state of affairs far more prevalent in the 'nineties. All the same there is still a great need for the elimination of verbosity and needless technical phrases. A comparison is drawn between a document and a picture; its frame, its outline, and its detail. Slipshod speech is deplored and we are enjoined to "speak clearly, slowly and deliberately" thereby often avoiding "a whole chain of misunderstandings and wrong directions."

It is probably not realised how much time is spent by the official in reading; accordingly the author stresses the importance of raising the speeds of average readers, without a corresponding decrease in the comprehension of the material read. It is doubtful whether Mr. Moonman is strictly correct when he asserts that the system of asking an applicant for a post what salary he is asking has been dropped; a glance at some of the advertisements for staff will show this. In an interview intended to determine whether a candidate is suitable for a post it is claimed that the interviewer must not remain "aloof and inscrutable" but must do his best to set at ease the one he is interviewing. It is essential that before such an interview takes place everything possible has been obtained relating to the man's past history and performance.

The value of suggestion schemes is discussed, and it is mentioned that one of the oldest was that of Hoover, Ltd., which in about a quarter of a century has produced over 30,000 suggestions resulting in more than 6000 awards.

The author is so impressed with the subject of obtaining and presenting information in a precise and logical manner that he devotes three chapters to it, before proceeding to consider the place of discussion groups in an organisation. Mr. Moonman might be interested to know that for many years a big Government factory held so-called "efficiency meetings" but as these were held "out of hours" the grumblers stayed away, whereas strange as it might at first appear grumbling often leads to constructive thought and action.

When management becomes haphazard a state arises which the author calls "grotesque and incalculable" and in the circumstances would strongly advocate a review of the management team. He further contends that it is essential in production to shorten the time taken, to attain more flexible control, to reduce cost, and to improve quality. For this it is necessary to gain the co-operation of the workers, especially when changes are in mind; it is agreed that to obtain this objective a systematic method to suit all conditions must be agreed.

In conclusion Mr. Moonman quotes the words of John Donne that "no man is an island entire in itself; each is a part of the continent," and finally that the goal of management should be: the running of an efficient enterprise, achieving satisfactory human relations, and meeting the needs of the community. A study of *The Manager and the Organization* will undoubtedly help towards this end.

PORE PRESSURE AND SUCTION IN SOILS

Proceedings of a Conference organised by the British National Society of the International Society of Soil Mechanics and Foundation Engineering, at the Institution of Civil Engineers, March, 1960.

Publishers: Butterworth and Co. (Publishers), Ltd., 4 and 5, Bell Yard, London, W.C.2. Price 60s.

THE importance of pore pressures in soil mechanics problems has long been recognised, but satisfactory techniques of measurement have been developed only in recent years; and whilst a considerable amount of theoretical work has been carried out on the role of pore pressure and suction in partially saturated soils, there appeared to be a substantial measure of disagreement between various research schools. This Conference therefore provided a very welcome opportunity for the exchange of ideas and the presentation of field and laboratory data.

Eighteen papers were read and these, together with some remarkably interesting discussions, are printed in the volume under review. The standard of book production is excellent and all the papers are well illustrated.

In fully saturated soils Terzaghi's equation for effective stress has been substantiated by numerous laboratory tests, but in the opening address Professor Skempton demonstrated theoretically and by references to experiments that this equation was not always strictly applicable to porous materials in general, such as rocks and concrete, and that even for soils it required modification when air as well as water was present in the voids. This latter point received attention in several other papers, notably by Mr. Aitchison from Australia, Professor Jennings from South Africa and Messrs. Croney and Coleman of the Road Research Laboratory. The whole question was admirably summarised by Dr. Bishop in discussion, who showed that the discrepancies in viewpoint were more apparent than real. His contribution is, indeed, the clearest statement yet made on what has for many years been considered a difficult and controversial subject.

Three papers deal with methods of pore pressure measurement but to the practising engineer the most useful material will be found in the records of such measurements made on actual structures. Mr. Little and Mr. Vail give information relating to two earth dams, and a comprehensive set of observations during the construction of Selset dam are recorded by Dr. Bishop, Mr. Kennard and Mr. Penman. Pore pressures in the upstream bank of a dam, during reservoir drawdown, have been measured in very few cases and the paper by Mr. Paton and Mr. Semple, describing their observations on the Glen Shira dam, is therefore particularly instructive.

Two unusual investigations relate to the pore pressures resulting from driving piles in soft clay, contributed from Norway by Dr. Bjerrum and Mr. Johannessen, and the observations of pore pressures set up in a deep bed of silt by the load of an oil tank. These measurements, given by Dr. Gibson and Mr. Marsland, constitute the first field record of pore pressures in soil beneath a foundation.

Finally mention must be made of the comments made by Dr. Schofield in various of the discussions. They are perhaps the last published statements made by this distinguished scientist before his tragically premature death in June, 1960, and contain a number of valuable remarks concerning the properties of soils and soil particles.

THE DETERMINATION OF GASES IN METALS

Special Report No. 68. The Iron and Steel Institute, 4, Grosvenor Gardens, London, S.W.1. Price 63s.

THE determination of some gases in some metals might be a more accurate description of the contents of this book because it deals mainly with oxygen, hydrogen, and nitrogen, and the metals are either iron or one or other of a relatively small selection of non-ferrous metals.

A note appeared in THE ENGINEER, August 5, 1960, on pages 237-8 about unprecedented joint meetings that were enthusiastically attended by 300 people who discussed fifteen papers. This was the first symposium held in Britain on the determination of gases in metals. It was organised by the Society for Analytical Chemistry in conjunction with the Iron and Steel Institute and the Institute of Metals. The meetings occupied two days and it was arranged that the Iron and Steel Institute should prepare a report of the proceedings as a bound volume. Hence it is that this book now comes to us as Special Report No. 68 of the Iron and Steel Institute. It contains all the printed papers, brief reports of the three verbal discussions, and some apposite correspondence.

Those who had been concerned with this subject for many years were the most impressed by what they heard, during those two days, of the advances in a wide variety of techniques that are now being applied to the study of gases in metals, with what obviously amounts to intense interest. Chemists and physicists working in a wide range of industries had been brought together for these discussions, but all were keenly interested in the development of better analytical methods for the determination of gases in metals.

Newcomers to this subject, who were not present at the meetings when these papers were presented and discussed, will find this book less easy to follow than it might have been had it been produced with a more obvious division into its three main sections and provided with a good index. The 308 pages of this book need and should have been provided with an index, but the time entailed in producing an index would have

REVIEW OF BOOKS *(Continued)*

delayed publication. Hence, while regretting the absence of an index, one must in fairness note this reverse side and commend the speed with which the report has been made available. It is not divided into chapters according to subject but prints the papers as they were presented. The first paper critically reviews the techniques for sampling liquid metals for gas analysis ; it gives special attention to the sampling of liquid steel from industrial furnaces for the determination of hydrogen ; and it favours evacuated glass tubes. On the other hand a modified bomb method is regarded as the best for oxygen samples and the author, Dr. Thomas B. King, also considers briefly the sampling of nitrogen and certain relevant laboratory techniques. The remaining papers deal with the determination of oxygen, nitrogen, and hydrogen in metals. Some of these original papers describe new techniques for the study of gases in metals, such as : vacuum fusion, semi-micro vacuum fusion, carrier-gas, activation, emission spectrometric, isotope-dilution, X-ray emission analysis, and internal-friction methods. Three very helpful review papers, covering twenty-four, twenty-seven, and thirty-two pages respectively, summarise methods now used for determining oxygen, nitrogen, and hydrogen. Each of these three is concluded by an extensive bibliography and these references (129 from W. T. Elwell, 163 from J. D. Hobson, and 114 from R. Eborall) will be much appreciated by serious students.

It is probable that several of these new techniques of gas determination will be developed to become routine control tests in the hands of the now highly essential shift chemists in many metallurgical production operations. This will be true not merely in the small quantity production of rather exotic nuclear energy and electronic metals, but also in the large bulk production of steels by new methods such as the L.D. process, because metallurgists have been surprised to find that some almost minute traces of certain gases critically affect the mechanical properties of commonly used metals.

Planning the symposium reported in this book was well worthwhile, and the gathering together in this volume of the papers, discussions and some added written contributions, will be welcomed by analytical chemists and metallurgists. The new knowledge thus made available helps to fill one of the gaps in our plans for control of production of many metals and alloys that are essential to engineering.

MATERIALS SELECTION FOR PROCESS PLANTS

Russell E. Gackenbach.

Publisher : Reinhold Publishing Corporation, New York ; Chapman and Hall, Ltd., 37 Essex Street, London, W.C.2.

Price 68*s.*

THE author of this book is a materials engineer in a large American chemical company and obviously has extensive first-hand experience of the service behaviour of materials of construction in chemical plants and of methods of corrosion protection.

One of the initial chapters gives the elements of corrosion theory and indicates the types of corrosion phenomena including the more insidious local and selective damage and stress-corrosion cracking. A resumé of suitable remedies is given in each case and there are additional chapters giving the principles of cathodic protection and the use of inhibitors. While the advice given is useful, it represents no more than an outline of possible solutions to the problems.

There is a short chapter on " Designing for Corrosion Protection " and this contains a lot of sound guidance and commonsense which is obviously written with a wide knowledge of the problems encountered and of the actions possible at the design and fabrication stage. This is a chapter that could, with advantage, have been enlarged considerably to give the information one would expect from the title of the book. In its present form the chapter is too concise to be considered more than a series of reminders to the reader sufficiently experienced to recognise the significance of some of the points made.

The above comment becomes particularly relevant in view of the fact that three-quarters of the book is devoted to a summary of the properties of materials of construction obtained principally from the publications of the producers and from the technical literature. The main advantage of the treatment is that ferrous and non-ferrous metals together with the more exotic metals and alloys, and also non-metallic materials such as brick construction and corrosion-resisting cements, the plastics, natural and synthetic rubbers are all included under one cover. Notable omissions include tantalum and impervious carbon and graphite.

There is an excellent final chapter on paints and coatings which emphasises the importance of designing for painting, surface preparation, selection of the paint system, the effect of film thickness and the advantages of regular inspection and maintenance.

The author has set out to produce a practical handbook for people in engineering maintenance and production. It is certainly a useful reference book for the readers he has in mind, and deserves attention from the more specialised technologist in the same field.

THE DEVELOPMENT OF THE ENGLISH TRACTION ENGINE

Ronald H. Clark, A.M.I.Mech.E.

Goose and Son, Ltd., Norwich. Price 84*s.*

A TRACTION engine is a " monumental " thing. Proudly it stands when in action before onlookers. The traction engine has pride in its output and justifiably wants the world to know it. Modern generations which have not seen in general use the giants of the traction engine era on roads or fields have missed a dramatic stage of England's steam power history.

But in words and illustrations they can relive the entire era of that history in competent and most pleasant form. A splendid volume—*The Development of the English Traction Engine*—is, up to now, the most complete record of the whole subject, and it has been written by a master-enthusiast—Mr. Ronald H. Clark, member of Council of the Newcomen Society. Fascinating, indeed, is the work. One learns, for instance, that the first English engine to fulfil the accepted definition of a traction engine was made for a foreigner. It was " a steam tug or drag made by Walter Hancock of Stratford-by-Bow in 1834 to the order of M. Voightlander of Vienna . . ." And the pattern of the boiler of that notable machine " was many years ahead of its time and to a certain extent anticipated some later forms used in steam cars sixty years after."

Well, the pioneers steamed powerfully through Britain's greatest industrial century, and the early days of the spacious Victorian era saw traction engine builders produce their brain-children in varied parts of the country, indeed. Staffordshire, Yorkshire and Lincolnshire produced many of the famous names, but there were manufacturers elsewhere from London to Hampshire and Wiltshire, and plenty of other areas where heavier iron and steel industries existed added their contributions. Railroad and stationary steam engine designers understandably played considerable parts in many aspects of development. Aveling, Fowler, Hornsby, Burrell and other names too numerous to mention individually, appear, and persist, through the years, and there must have been few countries in the world in which magnificent steam steeds bearing such honoured nameplates from Britain did not travel.

Mr. Clark's treatise is true description and history of the work carried out by steam engineers of genius, and it has some very fine original illustrations. Romance, too, can be well read into his many factual side references. One quotation will suffice to show his quality of research. It is from just one page of the volume's 390. It runs ; " In Figs. 15 and 16, however, we have an example of an under-mounted engine built by Dübs and Company, locomotive builders, Glasgow Works, in 1866. Named *Abdul Aziz*, it was designed for them by the late D. K. Clark and was supplied to the Ottoman Carrying Company for service in Syria, its route being between Damascus and Beirut, a distance of 68 miles . . ." What a picture of age-old travel through centuries by man and beast long before steam arrived, does not the mere mention of that historic area conquered by one of Mr. Clark's British traction engines bring to mind ?

A book very much to buy and keep.

MANUAL OF MAN-MADE FIBRES

C. Z. Carroll-Porczyinski.

Publishers : Astex Publishing Company, 22-23, North Street, Guildford. Price 29*s.*

THIS work provides in condensed form extensive information on all organic and inorganic man-made fibres by use of manufacturing flow charts, tables recording physical and chemical properties of fibres in the dry, wet and heated states and stress-strain diagrams. Textile fibre products and textile fibres are classified and sections of the book deal with : natural polymer man-made fibres; synthetic polymer man-made fibres ; inorganic fibres. Textured yarns are also dealt with and the book contains an identification section together with photomicrographs and X-ray diffraction photographs. There is an extensive bibliography covering publications concerned with the manufacture, properties and uses of man-made fibres, and this is followed by a list of producers in various countries, arranged alphabetically.

Fuel Loading at Berkeley and Bradwell

As recorded briefly in last week's issue the operation of loading the initial fuel charge at the first C.E.G.B. nuclear power stations was started about two weeks ago. Fuel loading began at Berkeley, No. 1 reactor, on August 12, and at Bradwell, No. 1 reactor, on August 14. From these dates it is expected that criticality will be reached in about two weeks at Berkeley and about six days at Bradwell. At each station the approach to criticality and the subsequent completion of fuel loading will initiate an exhaustive programme of running trials of the reactor, control equipment, instrumentation and generating plant, building up to operation at full power. The No. 1 reactor in both stations is due to be on full commercial load early in 1962.

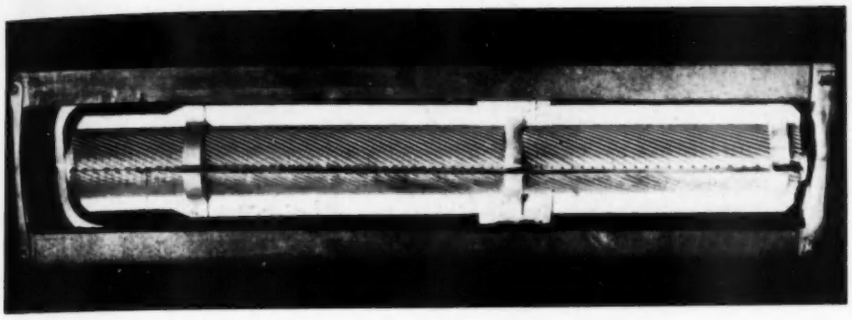


Fig. 1—Berkeley fuel element

It will be recalled that during normal operation at full temperature and pressure these reactors will be refuelled on-load, as required, by special machines mounted on the "charge-face" floor above the reactor core. However, for the initial charge, before the reactor has become radioactive it is quicker and more convenient to load the fuel into the graphite core by hand, as described below.

A short description of the fuel loading operations at Berkeley and Bradwell is given and some of the relevant data are tabulated here for convenience.

Fuel Loading: Berkeley, No. 1 Reactor

A fuel element for the Berkeley reactors is shown in Fig. 1. Each element consists of a fuel rod of natural uranium, 19in long by 1·1in diameter, encased in a finned can of magnesium alloy. It is mounted by two zirconium end brackets between two graphite struts.

Number of reactors	Two
Type of reactor	Gas-cooled, graphite, moderated
Fuel	Natural uranium in metallic rod form enclosed in finned magnesium alloy cans
Number of channels per reactor	3275
Number of fuel elements per channel	Thirteen stacked vertically in tandem
Total number of fuel elements per reactor	42,500 (approximate)
Total weight of uranium per reactor	232 tonnes
Total weight of graphite moderator	2000 tonnes
Net electrical output	275MW
Contractor	A.E.I.-John Thompson Nuclear Energy Company, Ltd.
Contract placed	December, 1956
Site work started	January, 1957
Scheduled completion (two reactors)	Late 1962

Before fuel loading began in No. 1 reactor, a series of stringent precommissioning tests was carried out on the reactor and its associated plant to demonstrate their efficacy.

All fuel arrives on site at Berkeley in metal containers and is received into the uranium fuel store (capacity 500 tonnes). As required, the sealed containers are transported by fork lift truck from the uranium fuel store to the reactor, about 100 yards away. At the entrance to the reactor building, the container is placed in a lift and taken to a small store on the fourth floor of the building. There, the container is unsealed and the fuel elements, each still separately bagged in polythene, are removed.

The elements are placed vertically in a small trolley and sent by a fuel lift to the fuel preparation room on the sixth floor, where "clean conditions" are strictly observed and each fuel element is carefully inspected after removal of the protective polythene and loaded into a special carrier (Fig. 2).

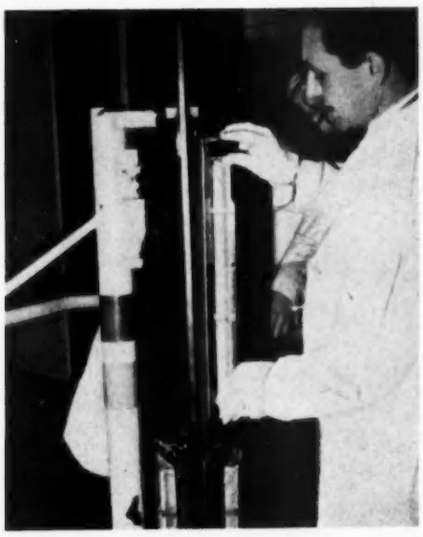


Fig. 2—Fuel elements for Berkeley No. 1 reactor are inspected and inserted in a special carrier after removal of polythene covers

When fully loaded the carrier is wheeled on a light trolley to the reactor charge face and is then lowered by cable through a refuelling standpipe into the reactor pressure vessel (Fig. 3). There operators stand on top of the graphite core structure, unload the fuel elements from the carrier, place them in a wheeled trolley and take them to the fuel channel to be loaded (Fig. 4) starting at the channel in the centre of the cylindrical core. Adjacent channels are filled uniformly around it in an expanding circular pattern.

Before any fuel is loaded, twenty-four control rods in the central region of the core, out of a total of 132, are lowered and locked in the "Down" position. These control rods cannot be withdrawn when manual fuel loading is taking place. The remaining 108 control rods are held in the "Up" position, ready to drop in instantly in an emergency.

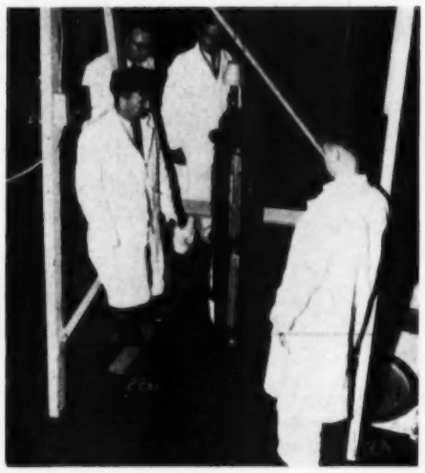


Fig. 3—Carrier with nine fuel elements being loaded through a fuel standpipe into No. 1 reactor at Berkeley

When 300 out of 3275 channels have been loaded, the operators leave the reactor vessel. It is then sealed and the twenty-four control rods are withdrawn. On the reactor charge face the neutron production in the core is measured and indicated by instruments on the reactor charge face. When this measurement has been taken, the twenty-four control rods are again lowered into the locked "Down" position in the core, the vessel is unsealed and a further 100 channels manually charged. Again the operators leave the vessel, which is then sealed, the twenty-four control rods withdrawn and neutron production again recorded.

This operation is repeated, with the number of fuel channels loaded between each test becoming progressively less. A curve is plotted of neutron production against the number of fuel channels loaded. From this

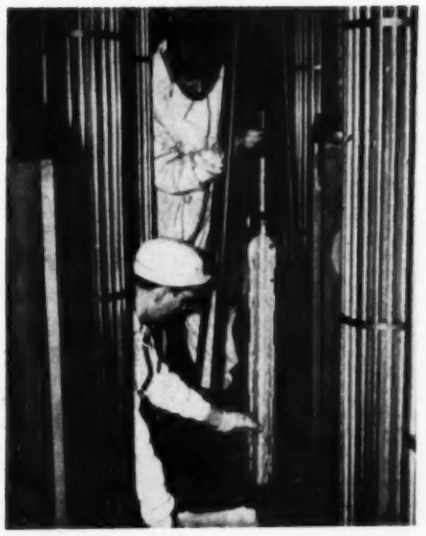
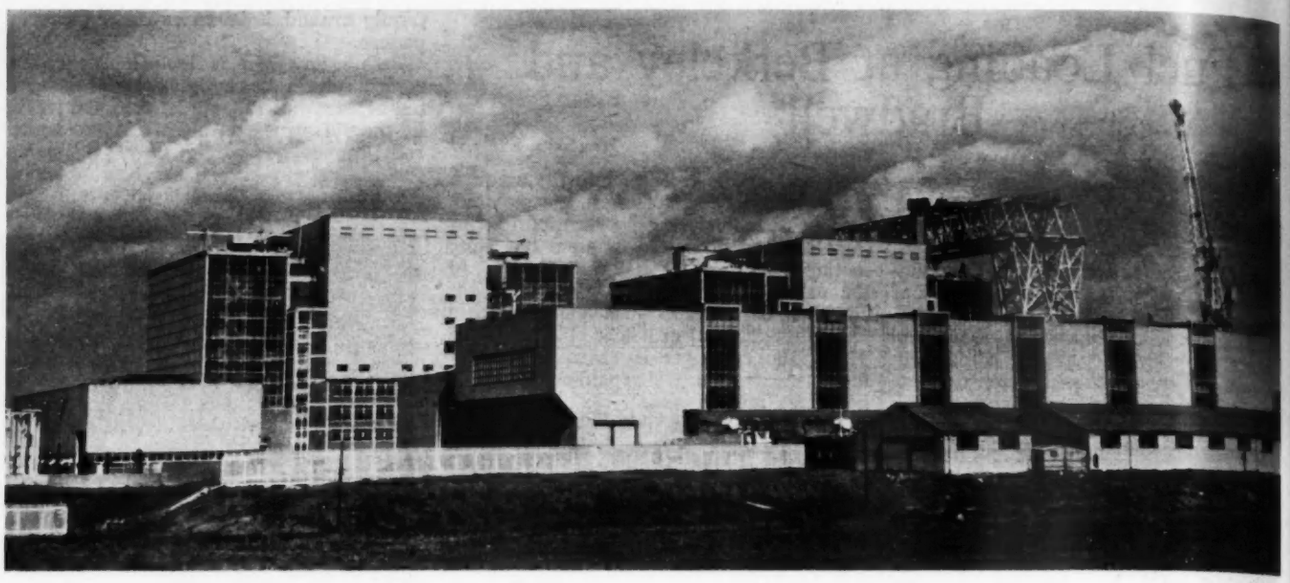


Fig. 4—Lowering a fuel element into a fuel channel in the graphite core at Berkeley



Work is well advanced on the construction of the first two commercial nuclear power stations of the Central Electricity Generating Board. They are Bradwell (net electrical output 300MW) sited on the southern bank of the Blackwater estuary in Essex, about 50 miles from London, and Berkeley (net electrical output 275MW) on the eastern bank of the Severn estuary, about halfway between Bristol and Gloucester. Both stations are being built for the C.E.G.B. by The Nuclear Power Group.

Each station has two graphite-moderated natural uranium reactors cooled by carbon dioxide. At Bradwell, illustrated ABOVE, the coolant is circulated between each reactor and the associated six boilers at 147 lb per square inch and the steam generated drives six 52MW turbo-alternators. At Berkeley, illustrated BELOW, the coolant pressure is 125 lb per square inch and there are eight boilers per reactor to generate steam for the four 83MW turbo-alternators.

As recorded in last week's issue the initial charge of fuel is being loaded into the No. 1 reactors at Berkeley and at Bradwell. A short description of the loading procedure is given in the accompanying article.

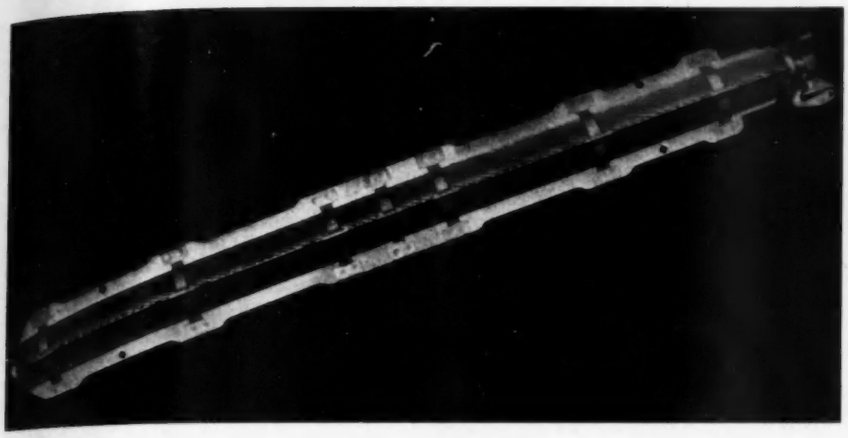


Fig. 5—Bradwell fuel element

curve, a forecast can be made of the total number of channels remaining to be filled before the critical mass is attained. The loading procedure is continued until this point is reached. However, the reactor is still not allowed to " go critical " (i.e. produce a sustained chain reaction) until a predetermined point in a series of tests carried out to check the various nuclear design calculations.

Intensive tests will be carried out over a period of two weeks to obtain nuclear data for the critical core. After completion of these tests, the loading of fuel continues by hand as before, interrupted by routine tests involving withdrawal of the control rods and establishment of sustained chain reactions at extremely low powers, until eventually the reactor is loaded with its full operational quantity of fuel. Until the reactor has been run at quite substantial power levels, radioactivity is low enough to permit entry to the reactor vessel.

With the reactor fully loaded with fuel, tests are carried out to calibrate the control rods. The final tests in the series will cover the equipment for the detection of faulty fuel element cans. The reactor will then be ready for proving tests at increasing electrical loads, until full power is reached.

The time taken from initial loading to criticality is expected to be fourteen days. Approximately 660 out of the total of 3275 channels will be filled to reach this stage, which represents a weight of fuel loaded of about 50 tonnes, compared with the total of 232 tonnes required to bring the reactor to the fully operational condition.

Although only about 50 tonnes is required for criticality when all the control rods are withdrawn, once the reactor commences to operate several influences tend to stop the reaction. For instance, increase in temperature of the reactor with power, and the production of fission by-products absorb neutrons and require compensation by inclusion of further quantities of fuel. Factors such as these account for the additional uranium which has to be loaded into the reactor subsequent to the attainment of the critical mass.

Fig. 7—Inspection of fuel elements on the Bradwell pile cap

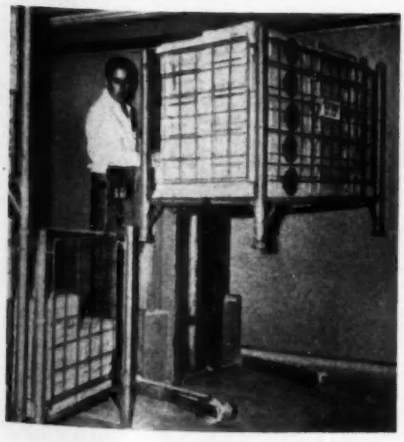


Fig. 6—The fuel element store in No. 1 reactor at Bradwell

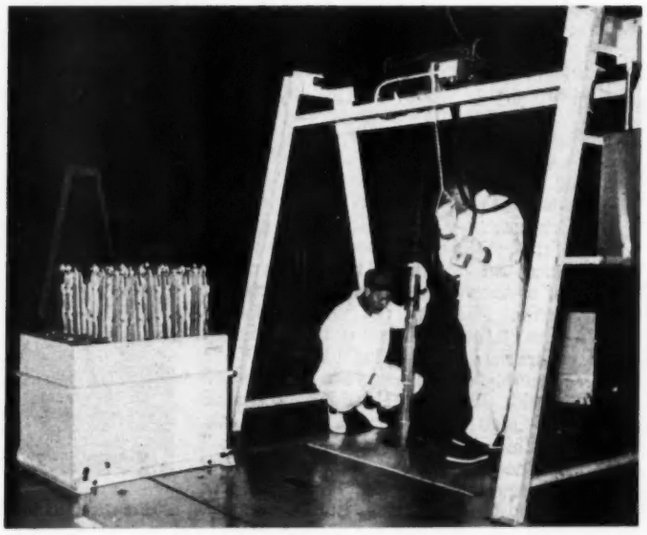


Fig. 8—Lowering a fuel element through a standpipe on the pile cap at Bradwell

Fuel Loading: Bradwell, No. 1 Reactor

A fuel element for Bradwell is illustrated in Fig. 5. It consists of a rod of natural uranium, 3ft long by 1·15in diameter, enclosed in a finned can of magnesium alloy. The spiral fins are intersected by four longitudinal splitters.

Number of reactors	Two
Type of reactor	Gas - cooled, graphite - moderated
Fuel	Natural uranium in metallic rod form enclosed in finned magnesium alloy cans
Number of fuel channels per reactor	2564
Number of fuel elements per channel	Eight, stacked vertically in tandem
Total number of fuel elements per reactor	20,520
Total weight of uranium per reactor	235 tonnes
Total weight of graphite moderator per reactor	2000 tons (approximate)
Net electrical output (two reactors)	300MW
Contractor	Nuclear Power Plant Company, Ltd.
Contract placed	December, 1956
Site work started	January, 1957
Scheduled completion (two reactors)	Late 1962

Fuel elements (each in a polythene envelope) are delivered to Bradwell in boxes stored (Fig. 6) in rooms in the reactor building. As required the elements are removed from the boxes, placed in transfer baskets and transported to the pile cap where there is an inspection area. The polythene covers are removed for inspection of the fuel elements (Fig. 7) which are then moved in trolley baskets to the loading area. There three open standpipes enable the fuel elements to be lowered singly by special hoists on to the final loading area on the top of the reactor core. Special hand grabs and friction pulleys are then used to load the elements in the channels. This handling equipment incorporates safety devices to prevent damage to the elements.

Fuel loading is started at the central fuel channel in the reactor core and is continued outwards, maintaining a cylindrical pattern. The early stages of fuel loading are interrupted at intervals and, with the reactor cleared of personnel, the control rods are withdrawn. A measurement of neutron flux on each occasion leads finally to a prediction of the critical loading.

The final stage of loading to criticality is designed to make the reactor slightly supercritical so that the reactor power will continue to rise when the control rods are withdrawn. This power divergence will be arrested at a very low power level by automatic reactor trip, thus demonstrating the achievement of criticality and the adequacy of the automatic safety devices.

From criticality onwards, throughout the fuel loading programme, measurements are made on the reactor which yield data useful to the designers and assist in the optimisation of the ultimate reactor performance. The adequacy of the control rod system is tested as one of the primary measurements. The time taken from initial loading to criticality is expected to be six days ; approximately 474 (out of 2564) channels are to be filled to reach this stage, the weight of uranium fuel in these channels being 38 tonnes.

From the stage in the loading programme at which withdrawal of the main control rods would cause the reactor to " start up " special precautions are taken to avoid this condition whilst operators are in the reactor. The control rod drives are locked in the disengaged position and the custodian of the key is responsible for controlling access to the reactor and preventing unauthorised adjustment of the control rod position. Secondly, instrumentation is installed to detect the rise in neutron flux level that would accompany reactor start-up and to cause all control rods to fall into the core by gravity, thus shutting down the reactor.

When the reactor has been fully loaded the reactor measurements will be continued, special attention being paid to the installed control rod systems, absorber elements, burst cartridge detection equipment and channel coolant flow adjustments.

The contractors for these nuclear power stations, A.E.I.-John Thompson Nuclear Energy, Ltd., and The Nuclear Power Plant Company, Ltd., are now partners in The Nuclear Power Group, the constituent companies of which are Associated Electrical Industries, Ltd., Clarke Chapman and Co., Ltd., Alex Findlay and Co., Ltd., Head, Wrightson and Co., Ltd., Sir Robert McAlpine and Sons, Ltd., C. A. Parsons and Co., Ltd., A. Reyrolle and Co., Ltd., Strachan and Henshaw, Ltd., John Thompson, Ltd., and Whessoe, Ltd.

Motor Car Assembly Building

A further stage in a comprehensive programme of re-organisation and modernisation has been completed by Standard-Triumph Group Services, Ltd., at Coventry, with the completion of a new vehicle assembly building. This building is designed and equipped to give an output of 300,000 *vehicles a year.*

A NEW building has been completed at the works of Standard-Triumph Group Services, Ltd., for the assembly of "Heralds," T.R. two-seaters, " Atlas " trucks, " Vanguards " and 10 h.p. vans. This building has three levels and bodies are delivered to its top floor where up to 500 can be stored on an elaborate system of motorised rollers and double strand conveyors. Control of the mechanised storage system on this top floor, to be seen in our illustration, is from a remote panel in the basement of the building. In the control system thirteen Marconi closed circuit television camera channels and associated equipment form an integral part of the automatic routing of the bodies. In the control room five 14in monitors provide pictures from five cameras installed at strategic points in the body storage area. This enables controllers to identify the various types of bodies arriving in the area and to keep the programming department constantly informed of the current position. Details of body colours and other relevant details are carried in code form on a card on each vehicle. Any of the remaining eight cameras can be switched on to a sixth screen so that a close watch can be kept on the passage of vehicles at all stages of progress. With this equipment a controller can check that the cars are moving along their programmed routes, and take steps in advance to avoid hold-ups.

Vehicle assembly takes place on the ground floor of the building, while components stored in the basement are brought to vantage points adjacent to the various assembly stations by twelve lifts. Handling the parts and sub-assemblies on the two floors is carried out by fork lift trucks and overhead hoists. Of the three assembly lines installed one is concerned entirely with the new " Herald," the second is for " Vanguards " and the 10 h.p. van, while the third is for T.R. cars and " Atlas " trucks. The conveyors and other mechanical handling equipment for the three lines was provided by Geo. W. King, Ltd., Stevenage, Herts, to the requirements of the Standard-Triumph Group planning engineers.

Assembly of the " Herald " begins with the lowering of the body from the store above by one of two 1-ton " Mansaver " grabs working alternately to give the required body feed rate of thirty per hour. The "Mansaver," which incorporates a hoist block and a fabricated steel sling specially constructed to suit particular loads, takes up its position above the point on the storage line to which the body is called from the stock lines. As the body halts beneath, the sling is lowered, feet are rotated, and the body lifted off its skid. The " Mansaver " waits in this position until called in automatically by the main line; it then traverses across to the aperture and lowers the body, crosswise, on to a drop table at the beginning of the assembly line. This drop table serves to position the body on to brackets or lugs on the conveyor. An air-operated ram raises a catch to engage with a lug beneath the slat platforms of the assembly conveyor and the table is then drawn forward at the conveyor speed. The body is lowered on to the assembly conveyor lugs during this movement and at the end of its travel the table is disengaged from the conveyor chain. The body continues its travel on the conveyor lugs and the table is returned by counterweights to its original position, where a limit switch causes the ram to raise it again ready for the next body.

The first section of the assembly line consists of a double strand floor conveyor of 195ft centres, having two chains with outrigger rollers running along channel tracks. It is 6ft 10in above floor level and runs through twenty-four 8ft assembly stations which have working platforms at either side and wells where necessary for underbody work. The assembly conveyor is driven by a 3 h.p. Brooks motor through a 9in Heenan and Froude electronically controlled coupling, and its speed is variable between 1ft and 4ft 6in per minute.

During the first assembly operation the final drive, springs, hubs, petrol pipes and fluid lines are fitted. A steering, tracking, castor and camber checking fixture is suspended by " Thor " balancers which take the weight of the fixture while assembly is completed. Engines, prepared on a separate line running parallel to the main assembly, are brought to the area in stillages by fork lift trucks and handled singly by an overhead gantry with a 5 cwt. hoist block. Engine preparation in this way reduces the number of completed types which would otherwise have to be kept in stock and controlled.

The prepared engines are suspended from an overhead hoist block incorporating a " Supertrack " runway and three power

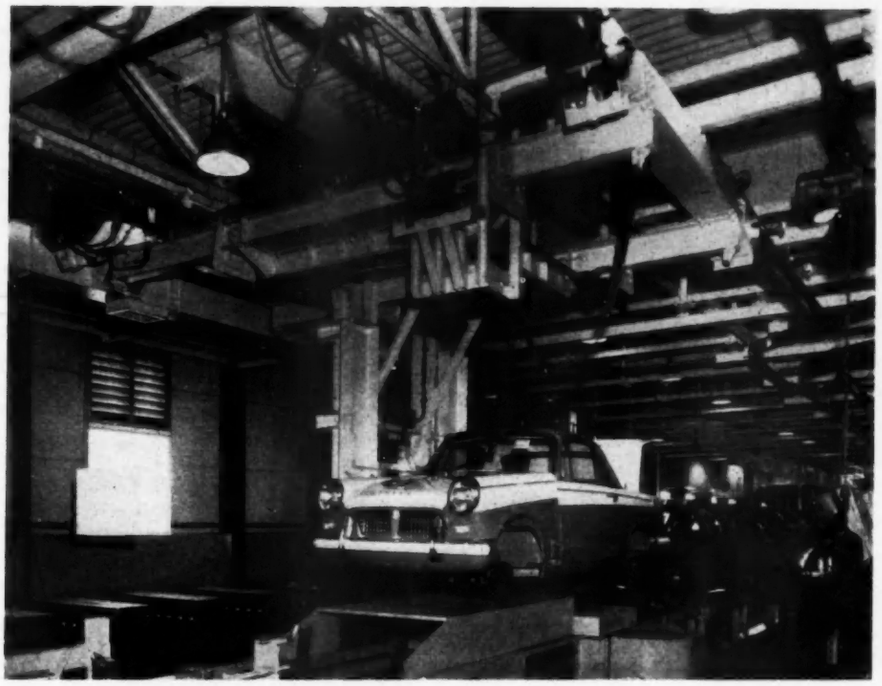
Bodies stored on top floor of assembly building on a system of motorised rollers and double strand conveyors

traverse hoists are circulated with waiting stations in which the engines are delayed until called for by the operators on assembly.

Transfer of the partially assembled vehicles to a second conveyor is carried out by a "Ski-Wracker" which lifts the body from the first conveyor, traverses, and after rotating, places it in the required location on the second conveyor for the continuation of assembly. The "Ski-Wracker," developed by Geo. W. King, Ltd., consists of forks mounted on a lifting carriage travelling on a vertical mast, which is connected to the underside of a turntable mounted in a crab traversing on an overhead gantry crane. As the body on the first conveyor passes a certain point, it operates a limit switch which calls the "Ski-Wracker" forward. The tripping of a second switch then causes the forks to rise with the body, rotate through 90 deg. while travelling, and lower the body on to a drop table. This table travels at the speed of the second conveyor whilst lowering the body and returns to its original position after completion of the operation.

On this second double strand floor conveyor, with the vehicle now in the forward drive position, a beam setting trolley is latched to the conveyor and the lights adjusted; seats are fitted and carpet trim added. A well in the line enables operators to couple up the exhaust, and bleed and adjust the hydraulic brakes and clutch.

An interesting point in this assembly section is the means used for delivery of wheels to the operators. Wheel and tyre assemblies from the basement stores are brought to the assembly area on overhead chain conveyor on special carriers from which they are automatically unloaded on to a gravity roller conveyor and fed into a chute each side of the track. Limit switches prevent the arrival of further wheels until those in the chute are used; alternate distribution of wheels to each side of the track is effected by a compressed-air cylinder operating a roller conveyor bridge which rises and falls over the first chute.



Automatic transfer of partially assembled cars to second conveyor is by "Ski-Wracker"

The final section in the "Herald" assembly line is a simple double slat conveyor synchronised with the chain conveyor behind. The slats are fitted with chocks for engaging front wheels of the vehicle, and transfer is effected by ramps, the front wheels being lifted clear from the end of the second conveyor lugs while the rear wheels are still being propelled along.

In this final stage, oil, petrol and water are added and the vehicle is started up and driven across a series of corrugations which shake down the suspension, and into a Burgess acoustic booth for mechanical and noise test. Under simulated road conditions a Heenan and Froude mechanical tester separately checks the brakes. The vehicle is next driven a few yards forward into the final inspection and test area.

For the assembly of the "Vanguards" and 10 h.p. vans a similar conveyor system to the "Heralds" is employed, but without the first section. Front cross members, suspension assemblies, rear axle sub-assemblies and engines are all made ready on two slat conveyors, and transferred to the assembly line by three 5 cwt. hoists on an overhead gantry, and a runway. A double strand conveyor takes the completed underbody units through final stages ready for body mounting. The bodies are brought from the store above by King two-fall hoist blocks. The vehicle passes through its various stages of assembly, wheels are brought to the appropriate and transfer is effected to the run-off slat conveyor for final test and inspection. The line used for T.R. and "Atlas" truck assembly employs three conveyor sections.

Control of all the assembly conveyor lines is effected from a central control room on the assembly floor. Here a mimic diagram indicates movement of mechanical handling equipment, showing whether a stoppage is due to mechanical breakdown or whether the line is temporarily stopped by an operation at a local control point.

One of the two 1-ton grabs lowering a body to the beginning of the assembly line from the mechanised storage area on the top floor of the new building

WELDING OR CUTTING BLOWPIPE.—A blowpipe which, by simply changing the nozzle, can be converted from a cutting torch into a welding torch, is made by the Suffolk Iron Foundry (1920), Ltd., Stowmarket. This "Double Duty Demon" blowpipe weighs only 1¼ lbs, and is stated to be easy to manipulate. It is designed to cut sheet metal and steel plate up to 2in thick, and to weld steel up to ¼in thick. The torch is supplied with three welding and two cutting nozzles to cover most of the requirements of everyday welding and cutting.

Letters to the Editor

WHAT IS TRAFFIC ENGINEERING?

SIR.—In your issue of August 4, Brigadier Lloyd's article on "Traffic Engineering Examined—Is it Engineering?"—and your editorial, "What is Traffic Engineering?" made me think you might be interested in the syllabus of the Traffic Engineering paper which will be included in the Institution Examination. At least it will give you some idea of what Council regards as the scope of traffic engineering, and how much "engineering" (as generally known) there is in it.

1. Techniques for traffic surveys; the measurement of flows, speeds, transverse positions, origin and destination patterns, journey times, delays, saturation flows, parking surveys.

2. Characteristics of traffic; typical results of surveys.

3. Statistical methods applicable to traffic engineering; the assessment of "before and after" studies, tests of significance, sample sizes.

4. Road design: vertical and horizontal alignment, gradients, sight distances, transition curves.

5. Junction design: uncontrolled junctions, channelisation, roundabouts, traffic signals, multi-level junctions.

6. Capacity of rural and urban roads: theoretical, observed, practical, economic.

7. Capacity of junctions: traffic signals, roundabouts, slip roads, multi-level junctions.

8. Location of roads in rural and urban areas: traffic assignment.

9. Economics of road planning: methods of assessing the economic return on road projects.

10. Amenity: the creation and preservation of amenity in relation to road planning.

11. Road surface characteristics: skidding resistance, riding quality, light reflectivity.

12. Street lighting: general principles, effect of road surface, Code of Practice.

13. Traffic signs and carriageway markings.

14. Parking needs: maximum demand, turnover characteristics, duration characteristics, generation by land use, design of on- and off-street parking facilities.

15. Road user characteristics: perception and reaction times, judgment of time intervals, pedestrian behaviour, speed/flow relation, effect of propaganda, driving skill.

16. Effect of traffic regulations: one-way systems, speed limits, parking restrictions.

17. Accidents: the effect of various traffic engineering measures on accidents.

Meetings of the Traffic Engineering Study Group, which was set up by the Institution of Civil Engineers and which held its first meeting in October, 1959, have been attended by an average of nearly 200 persons. The value of these meetings is unquestioned. Their title has now been changed to the Traffic Engineering Group.

A. McDONALD
Secretary

Institution of Civil Engineers,
Westminster,
August 17, 1961.

SIR,—May I humbly suggest that engineers whose business it is to plan and regulate road and/or rail traffic should link themselves with work study engineers and "The Institute of Works Study." The Institution of Civil Engineers will continue to cater for all those engineers who design and construct the necessary roads from the deliberations of the traffic study engineer.

D. D. W. COLE

Hindhead,
August 10, 1961.

CANALS IN THE ECONOMY

SIR,—Your columns are so often filled with despairing talk of the conversion of railways into roads, and attempts to prove road safety by comparing deaths on the M1 with those on the entire 20,000 miles of the railway network, that members of this Association were doubly surprised to read in your issue of August 11 a leading article, on the proper place of canals in the economy, that put forward the views and arguments of the Association with more cogency and strength than has often been the case with a paper of such a responsibility as THE ENGINEER. I have little to add to your comments unless it is to amplify the remarks concerning the value of inland waterways for water supply. You quoted the quantity of water sold by British Waterways as 200,000 million gallons per year. The published figure for income from this sale is only £500,000, or 0·6 pence per thousand gallons. When you consider that in most cases drainage of the heated or contaminated waste is also included in this figure and that the cost of water from other sources is of the order of 10 pence per thousand gallons, drainage not included, then the potential income from this source alone indicates that the annual deficit of British Waterways could be wiped out several times over were the Transport Commission as keen to alter the outmoded laws governing the price of water as they are to alter it to abandon the very source of the profit.

M. J. MACFARLANE,
Hon. Joint Secretary.
Inland Waterways Association, Ltd.,
Wolverhampton,
August 14, 1961.

A LOCOMOTIVE HISTORY—THE "ATLANTIC"

SIR.—In studying Mr. Poultney's letter in your issue of August 4, I find there are several points which need correction or amplification.

Great Northern Railway Locomotives.—The first of the larger Ivatt 4–4–0s appeared in 1898 not 1897. 4–4–2 No. 990 was not superheated in 1909 and Fig. 14 shows this locomotive after it had been restored for preservation in the Railway Museum at York. It will be seen that the brass beading has been removed from the splashers and that the cab side is fitted with a windscreen—an L.N.E.R. modification. The small "Atlantic" No. 988 retained its short smokebox when superheated in 1909. Fig. 15 shows No. 251 after the chimney, dome, firebox and trailing axlebox had been modified as a result of extended trial running. When superheating was first applied to the "Atlantics" the boiler pressure was 150 lb per square inch, but this figure was subsequently raised to 170 lb per square inch.

North Eastern Railway Locomotives.—While the first Worsdell "V" "Atlantic" appeared in November, 1903, several modifications were introduced in the second of the class (illustrated in Fig. 17) which was turned out in January, 1904. The remaining eight "V's" were all built in 1904. The modified design represented by No. 696, shown in Fig. 18, was known as class "V.1." and appeared in 1910. Sir Nigel Gresley's paper on three-cylinder locomotives was, I believe, read at the Institution of Mechanical Engineers in 1925.

Great Central Railway Locomotives.—"Atlantic" No. 258 was a Smith three-cylinder compound.

Great Western Railway Locomotives.—While any inferiority in the performance at high speeds of an "Atlantic," as compared with a 4–6–0 differing solely in the matter of wheel arrangement, would be attributable to the greater tendency of the four-coupled engine to nose, the six-coupled locomotive would be markedly superior where a high tractive effort was demanded. A two-cylinder locomotive tends, as one Chief Mechanical and Electrical Engineer has put it, to "rise in the stirrup" when starting a heavy train, due to the transfer of weight to the trailing axle. This can cause an appreciable reduction of the factor of adhesion, and "Atlantics" in general are very prone to wheel slip. A further point is that a locomotive with a short coupled wheel base is more seriously affected by a greasy patch on the rails, e.g. in the vicinity of water columns, than is a 4–6–0 type. The Western Region has some notoriously difficult stretches of main line, the worst being the Hemerdon incline between Plymouth and Newton Abbot where fallen leaves render the rails extremely slippery in the autumn, and an "Atlantic" would be a most unsuitable type to employ on a heavy train over this route.

J. D. GOFFEY

West Worthing,
Sussex,
August 18, 1961.

SIR,—In your July 28 issue, page 125 shows a picture of an "Atlantic" locomotive in an article by Mr. E. C. Poultney, O.B.E. The date is printed as 1892 and the locomotive as belonging to the L.N.E.R., which I am sure is wrong—Mr. Webb was a L. & N.W. chief engineer. I have travelled behind the engine many times in its day, and when painted in its special colours: "Queen Empress," No. 2054, and built in 1893 not 1892; Sister to "Greater Britain," built in 1891. The eight others of the same class of which but ten in all were built, came out of Crewe in 1894.

H. G. HIPKINS

Birmingham,
August 2, 1961.

Stress-Relieving First Pressure Vessel at Hunterston

The operation of stress-relieving the first pressure vessel at Hunterston nuclear power station is described. Radiant heating was used, applied mainly by bare strip elements. The maximum demand on the South of Scotland Electricity Board's system was 3·6MW, that is 2kW per ton of metal treated.

STRESS-RELIEVING of the first 70ft diameter reactor pressure vessel at Hunterston nuclear power station, Ayrshire, Scotland, has been completed. The station is being built for the South of Scotland Electricity Board by the G.E.C. and Simon-Carves Atomic Energy Group. The construction of the pressure vessels was subcontracted to the Motherwell Bridge and Engineering Company, Ltd., whose contract included the responsibility for the stress-relieving. In this operation about 1800 tons (1830 tonnes) of steel, situated at a mean height of 85ft (25·9m) above ground level, was heated to a temperature of 550 deg. Cent., soaked for twelve hours and then allowed to cool slowly. During the process accurate control was essential to limit the temperature difference between any two points in the shell.

Installed inside the pressure vessel and undergoing stress-relieving at the same time were the inner heat shield, the core-support grid, and the main gas seal between the walls of the inner heat shield and the pressure vessel. Certain parts of the hot and cold gas ducting and the nozzles for the charge/discharge and control-rod standpipes which penetrate the pressure shell were also included. The steel restraint beams for the graphite core were suspended from the inner shell nozzles, and other items treated at the same time were laid on top of the grid cover plate.

Heating Scheme

The electric heating system used was proposed and designed by the Industrial Advisory Service of the South of Scotland Electricity Board, who acted as consultants for the heating scheme to the Motherwell Bridge and Engineering Company, Ltd.

The pressure vessel and included components were heated by a series of freely radiating "Brightray" strips supported by wire links and ceramic insulators. Some strips were mounted circumferentially between the spherical pressure vessel and the cylindrical inner heat shield, while others on the top and bottom crowns followed approximately the curvature of the vessel. With the system of heater suspension employed, a curtain-like structure of heater elements was built up in the space between the inner heat shield and the pressure vessel. "Brightray" heater strips were also placed underneath the support grid (as illustrated here) to ensure that it would be adequately heated. Enclosed tubular-type heaters were used for each of the gas ducts. The method of suspension was very flexible, to permit the switching off of one heater without fear of damaging the suspension of neighbouring heaters.

The fabricated structure, including gas ducts, was divided into forty separate heating zones. By choosing suitably dimensioned heating strip it was possible to use 100ft (30·5m) lengths connected directly across the 240V mains. This length of strip was chosen because it was half the circumference of the spherical pressure vessel, enabling the supply to be brought in at one side of the vessel and the neutral connection to be taken out of the other side.

Heaters.—Except for the ducts, all heaters were made of "Brightray" strip. For the top crown the section of each heater strip was slightly reduced. Inside each zone the heater strips were connected in groups, each group being supplied from an externally-mounted auto-transformer fitted with voltage ratio adjustment which allowed a measure of control to be exercised over individual heating groups.

Each duct heater was of stainless steel 8in (20·3cm) in diameter and 6ft (1·83m) long, with a rating of 24kW at 240V. Two such heaters were used in each hot gas duct, and one in each of the shorter cold gas ducts. The duct heaters were supplied by Duncan Low, Ltd., Glasgow.

Insulators and Support Links.—Although the linkage system between element arrays varied from zone to zone, only one type of ceramic insulator was used throughout. All the support links were of "Incoloy D.S." wire which has a tensile strength of 10·5 tons per square inch (1650 kg per square centimetre) at 800 deg. Cent.

The stress in the most heavily loaded link at this elevated temperature was less than 0·1 tons per square inch (15·7 kg per square centimetre) so that a high mechanical factor of safety was provided. This wire has a melting point of not less than 1320 deg. Cent. and a coefficient of expansion of $18·5 \times 10^{-6}$ per deg. Cent.

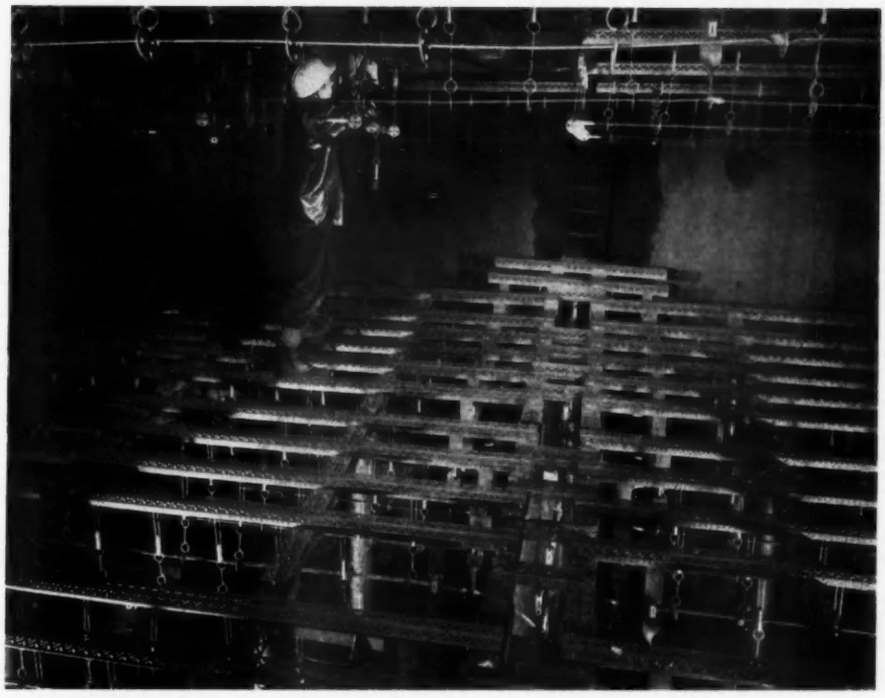
Thermocouples.—Temperatures were measured at about 400 points by means of chromel-alumel thermocouples. All the internal and external positions for the permanent thermocouples were used and in addition a number of temporary points were selected. The readings from these thermocouples were recorded by two different instrumentation systems, described later.

Particular attention was paid to the positioning of thermocouples on the pressure-vessel support skirt, gas-duct stubs, and sphere. It was possible to record the temperature distribution down the support skirt in various planes around its periphery, to assess the performance of the thermal pocket at the top of the skirt.

The temperature along each gas-duct stub was measured at several points to ensure that no large temperature gradients occurred. In addition, four pairs of thermocouples were connected differentially to record any temperature variation between selected points at the top and bottom of the large irregular-sectioned forgings at the duct roots. A pair of thermocouples, one connected to the top crown and the other to the bottom crown, were arranged to indicate the temperature difference between the two points, thus enabling the controller to regulate the heat input to keep an even temperature throughout the pressure vessel.

The vessel could be symmetrically divided into four quadrants, and it was reasonable to assume that the heating pattern would be similar in each quadrant. Thus it was decided to connect strip-chart recorders to the thermocouples in one quadrant only, with a few check thermocouples in the other quadrants.

In addition to the thermocouples used for the pressure vessel and its contents, about twenty were placed in the surface of the concrete biological shield at the equator level, on the concrete beams forming the soffit, and in the concrete supporting the reactor skirt, to ensure that the rise in concrete temperature was not excessive. Thermocouples were also used to measure the



Installing the electric heating strips under the support grid of the first reactor at Hunterston in preparation for stress-relieving. The bare heating strips are supported by wire links and ceramic insulators

temperature of the heater strips at various points.

Instrumentation

To eliminate the fatigue of the continuous logging of large numbers of temperatures by an operator, two special instrumentation and recording systems were employed. Approximately three-quarters (i.e. about 300), of the thermocouples were connected to a digital tyrewriter recording system which presented the temperatures in the form of a printed list, while the remaining quarter (about 100) were connected to six strip-chart recorders. This procedure was adopted for two reasons. Firstly, the strip-chart recorders could be used to control the heating cycle for a limited period in the event of failure of the digital typewriter system (or vice versa), and secondly, the strip-chart instruments provided a record which could be interpreted more quickly and easily than that of the digital typewriter.

As readings of the temperatures were taken from the recorders they were plotted graphically on a specially-constructed peg board in the control room. On this board temperature was plotted horizontally (in 5 deg. Cent. steps) and the 100 thermocouples were plotted vertically to give an overall picture of the heating pattern.

Next to this board were two models, one of the pressure vessel and the other of the inner heat shield resting on the grid. Fixed to the models were small lamps in positions corresponding to those of the 100 thermocouples represented on the peg board. By placing a small plug in a thermocouple position on the board the appropriate lamp on the model lit up. Thus the position of a thermocouple in the vessel could be located quickly if it showed that the temperature in that part was differing too widely from the mean temperature of the whole structure. Remedial action could then be taken by reference to electrical control information on the peg board.

Two other display systems formed part of the peg board. The first showed the power loading of each heater circuit in the pressure vessel and the tapping position of each of the twenty-four auto-transformers; the second showed the cycling of the tubular duct heaters. The complete peg board and models were designed and constructed by the South of Scotland Electricity Board Industrial Advisory Service.

The equipment for the digital display system was specially developed by G.E.C. and was arranged for either automatic or manual operation. On automatic operation all the thermocouple readings were sequentially scanned and printed out by an I.B.M. electric typewriter. Special observation of particular thermocouples could be achieved by selecting and printing a fewer number of temperatures more frequently. On manual operation, by the use of a push button, individual thermocouple readings could be selected and logged by the control engineer.

Four uniselectors having gold-plated contacts, shared equally the 300 thermocouple circuits. The uniselectors were driven by relays which were electrically interlocked with the indicators and print-out system to control the logging sequence. The output side of each uniselector was connected to an "Electroflo" type-198 potentiometric indicator scaled to read 1000 deg. Cent. The balancing time of the indicator was nominally one second, but if the difference between the two successive temperatures was small, this time was greatly reduced. To take advantage of this, balancing detectors were fitted so that print-out was initiated immediately all four indicators were balanced.

Each indicator was also fitted with a Hilger and Watts digitiser having an output in the Watts reflected decimal code. When the four indicators were balanced, the output of each digitiser was decoded in turn by a single decoding unit and passed to the electric typewriter. Once during a complete scan, i.e. through all four uniselectors, each indicator was connected to a standard reference (corresponding to a reading of 800 deg. Cent.) for checking whether the logging installation was functioning correctly. Accuracy of the potentiometric indicators was 0·25 per cent f.s.d. and the accuracy of translation was ±1 digit. The system was calibrated at 550 deg. Cent. and a correction card was made to cover other temperatures.

Since the electric typewriter was able to print ten digits per second, multi-bank uniselectors capable of switching the inputs of the four indicators simultaneously were employed, the four outputs being printed out sequentially. The print rate was thus 2½ digits per second.

Additionally the five differential thermocouple readings were registered on a separate chart recorder for special and continuous observation.

"Rocksil" thermal insulation applied to the bottom crown of the first reactor pressure vessel at Hunterston. The charge nozzles were insulated individually and then covered by a thin aluminium container as shown

Power and Thermocouple Cabling

Because of the high temperature involved, special arrangements were adopted to take the power supplies to the heating elements and from the thermocouple points inside the pressure vessel. Stainless-steel conductor rods were used for the power connection to the heaters, groups of these rods being taken in through the charge nozzles to supply the bottom crown and grid heaters, through the cold gas ducts to supply the curtain and through the control-rod nozzles to supply the top-crown heaters. Welded joints were used between all the heater strips and the stainless-steel rods to prevent faults at these points during stress-relieving.

Mineral insulated stainless-steel-clad cables were used for all thermocouple leads. These cables were grouped together and brought out through nozzles in the pressure vessel. Outside the pressure vessel the mineral insulated cables were terminated in junction boxes from which normal multicore cables were run to eight further junction boxes in the control room. The leads from these boxes were then taken to the temperature-scanning equipment.

Power Supplies

Although the South of Scotland Electricity Board made a 4·5MW supply available for the stress-relieving, the maximum demand never exceeded 3·6MW, corresponding to 2kW per ton of metal treated. Power was taken from the main site substation through circuit-breakers to four 1000kVA 11/0·415kV three-phase transformers. Each of these transformers supplied six 150kVA single-phase auto-transformers, two per phase in parallel, having voltage ratios of ten equal steps. The auto-transformers were also individually switched to provide cycling control if the minimum voltage tapping obtainable proved too high.

Thermal Insulation

All external surfaces of the pressure vessel, ducts, and nozzles were thermally insulated as illustrated here. Usually this insulation consisted of two 3in-thick (76·2mm) layers of "Rocksil" but in some instances, namely round the duct stubs and skirt, the thickness was increased to 12in (30·4cm). Aluminium foil was widely used to reduce radiation and so protect the concrete surfaces.

The inner layer of "Rocksil" had a density of 9 lb per cubic foot (0·14g per cubic centimetre) and was backed on each side with a layer of 1in (25mm) mesh galvanised wire netting. The outer layer was of similar construction but its density was 6 to 7 lb per cubic foot (0·095 to 0·11g per cubic centimetre) and a 0·001in (0·025mm) layer of aluminium foil was interposed between the insulation and the wire mesh on the outer face.

Experimental work had already established that a 12-in (304·4cm) thickness of "Rocksil" was required on each side of the vessel support skirt to achieve an acceptable temperature gradient down the skirt under reactor operating conditions. Further investigation indicated that this thickness was also enough for the stress-relieving operation. The increase of thickness of insulation on the duct stubs where they passed through the 8ft square (2·44m) openings in the inner biological concrete shield ensured that the temperature of this concrete did not exceed 150 deg. Fah. As a further precaution against undesirable increases in the temperature of the concrete, arrangements were made to pass about 300,000 lb (136,400 kg) of air per hour through the biological shield cooling system.

Stress Relieving Operations

Telephones were installed to link the control room, housing the temperature recording equipment, with the four switching positions. The controller was responsible for co-ordinating the readings from the various heating zones and for issuing instructions to the switching operators.

As there was no previous experience to draw on for controlling the heating rate of vessels of this size and complexity it was not possible to lay down a set of rules governing the operation. Initially the bottom crown heaters were switched on at their lowest setting, i.e. half load, and held at this level until the heating pattern emerged. The switching instructions were then based on this pattern. It was agreed to limit the rate of temperature rise to less than 5 deg. Cent. per hour and on this basis it took about seven days for the pressure vessel to reach the stress-relieving temperature of 550 deg. Cent. at which it was soaked for 12 hours. Throughout the operation there was no heater failure. As would be expected the overall rate of heating was controlled by that of the bottom crown, because natural convection tended to take the heat away from this part of the sphere. After the soaking period the vessel was left to cool for nine days before removing the thermal insulation. Entry to the vessel was delayed a further two days.

Subsequent Tests

Various tests have since been carried out on the fabricated structure to confirm the success of the stress-relieving. These tests were laid down by Lloyds Register of Shipping (Land Division), with the approval of the U.K.A.E.A., the South of Scotland Electricity Board, and the consultants to the Board, Messrs. Kennedy and Donkin. They included crack-detection tests on 10 per cent of all nozzle welds on the inner heat shield and on the grid, and 100 per cent crack-detection tests of the nozzle welds in the shell and on the gussets. Ultrasonic examination of selected areas on the top and bottom crowns was also carried out.

The absence of any faults in the pressure vessel or its contents indicated that the stress-relieving was entirely successful. Certain minor modifications to the layout of the heating system should result in a reduction in the time taken to treat the second reactor pressure vessel. The use of radiant-heating strips, freely suspended inside the vessel, has been fully justified by the result. An advantage of this sytem is the ease with which it could be dismantled and to a large extent used again for the second reactor.

Clean Air for City Streets: Vehicle Fumes go Upwards

By T. HENRY TURNER

IN the coming years we expect to use internal combustion motors to propel increasingly numerous road vehicles. The exhaust fumes from this multitude of vehicles will be a nuisance and they must be eliminated before they amount to a serious danger. We must make provision now for these road vehicle exhaust fumes to be dissipated before they suffocate or poison people in our narrow streets and nearby basements.

The fumes that vehicles bring into our cities are mainly the result of the combustion of their fuels, which are of course based on paraffin, petrol, benzole or alcohol. Burning such fuels in well tuned engines produces in the exhaust pipes a mixture of hot nitrogen, carbon dioxide, carbon monoxide, fine particles of oil, and moisture that is corrosive, being acidified by oxides of sulphur that is always present as impurity in the petrol, or diesel fuel. Fuel technologists and chemists can express the composition of the various fumes that are exhausted from various types of internal combustion engines, as specialists, in their appropriately careful, detailed and quantitative manners, but it suffices here to note that :

(*a*) No man can continue to breathe only engine exhaust ; it will not support the life of human beings.

(*b*) Some constituents of engine exhausts are subtly poisonous, like carbon monoxide : other constituents normally present in very small quantities are suspected of causing cancer.

(*c*) Where the engine is badly tuned, or deliberately misused, clouds of black smoke or bluish oily vapours may obviously contravene the intention of the Clean Air Act.

Where are exhaust gases emitted?—A road vehicle in which the present writer had the pleasure and excitement of riding, about sixty years ago, was driven electrically and so caused no nuisance of engine exhaust noise and smell. However, it seems that we are likely to use internal combustion engines in our ever-more-congested streets for many years to come, so we must now study how exhaust fumes are emitted and where they go. No progress has been made in this matter for half a century because the exhaust pipe arrangement to be seen on modern cars is the same in general layout and intention as that of the beautiful little Calthorpe two seater, on which the writer's brother-in-law taught him to drive fifty years ago ; it had engine at the front and exhaust pipe under the seats leading to the rear as is still the most common practice.

In the meantime this practice has become much more poisonous than it was in the early days as may be seen from Fig. 1.

This reminds one that in the present-day stop-and-start, crocodile type of city driving the heater fan of Car No. 2 sucks in the low emitted exhaust fumes of Car No. 1. The odour of the other car's exhaust fumes is objectionable, the carbon dioxide and acid moisture no help and the carbon monoxide dangerously poisonous to the passengers in Car No. 2. This fan-assisted sucking in of other car's exhaust fumes is worst in congested city streets and on windless days. Experienced drivers of expensive modern cars, therefore, switch off their heaters in traffic ; hoping that they will breathe fresher air by temporarily discarding the heater accessory that they purchased to give them comfort. Odd isn't it? And all because the exhaust is emitted as low as possible.

The rear exhaust is sometimes bent out towards the offside, a common practice on British buses and some heavy lorries. These often have surprisingly wide exhaust pipes that appear to be 3in in diameter and Fig. 2 shows how they may frighten a child and infuriate a mother, as she pushes her infant in a low pram or push-chair on the pavement that has been expressly made for pedestrians. The driver does not intend to use his exhaust like the scythes on Queen Boadicea's chariot wheels nor does he intend the occasional backfires that are even more frightening for children.

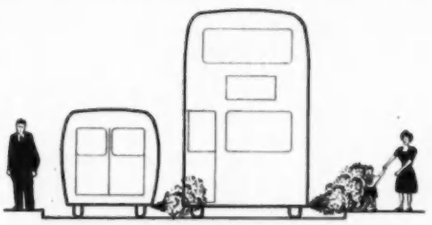


Fig. 2—Offside low exhaust in one-way city street blasts straight into child's face on pavement expressly made for pedestrians. A mother was furious about her child being thus callously assaulted in Nottingham 1961

Fig. 3 shows how we "see in a glass darkly" when the exhaust from a badly maintained or operated diesel bus or lorry sweeps the clear-view-ahead right off the road, for both lanes of traffic. Because the exhaust is by tradition thus emitted at a low level we are in this way subjected to annoyance ; obnoxious, dirty, smelly smoke that may sometimes be a real danger to life and limb.

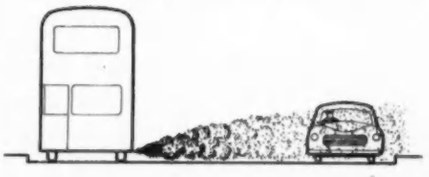


Fig. 3—Every time this inter-city bus started its black smoke emission reached the far footpath 15 to 20ft away! Seen between Derby and Nottingham 1961

Fig 4 shows how low exhaust fumes

Fig. 1—This sucking in of other cars' exhaust fumes is worst in congested city streets on windless days ; least in open stretches of country roads. But there are more people in cars in cities than those who should be poisoned in 1961

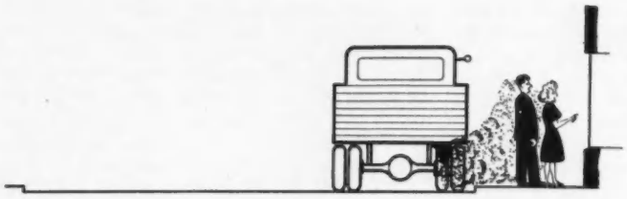


Fig. 4—Big lorry pulls up on offside of street where people are looking into shop window. They are driven to move away by the low engine exhaust

have been seen to affect shoppers when a big lorry pulled up on the offside of a street where people were gathered to study what was in a shop window. The exhaust fumes made them lose interest in the shop and they moved away to avoid the fumes from the lorry. This really amounted to an assault but is not preventable by the driver so long as designers arrange for horizontal low exhaust emmission.

People often have to edge their way behind a car or other road vehicle, with another vehicle's bonnet within arm's reach, in order to cross a street from one pavement to the other, even at recognised pedestrian crossings. The exhaust from the leading vehicle is then a real nuisance to many pedestrians especially when it is directed backwards horizontally. If, as in some reardoorway vehicles, the end of the exhaust pipe is made by the manufacturers so that it bends downwards towards the roadway, pedestrians are not so badly affected by the fumes of the exhaust from the vehicle that unwillingly impedes their crossing because it is caught in a traffic jam. (See Fig. 5.)

By watching the larger commercial vehicles as they pass on the road one may see that there are now many different ways of emitting their exhaust gases. Lorries often have a large expansion chamber silencer in the middle of their length ; either on the right or on the left under the body, and the exhaust is led from that by a short horizontal pipe to the offside or bent downwards on the nearside. Some lorries and many buses have horizontal exhaust pipes at their rear pointing out over the roadway. When these are seen emitting black smoke the power of the blast may be recognised because it frequently stretches 20ft, right across a wide road to the far pavement. I have observed that from an inter-city bus, more than a nuisance, it was a real danger every time its driver opened his throttle.

Occasionally one sees big lorries with the exhaust pipe almost under the driver at the front on the offside. In almost all such vehicles it should be possible, with a little ingenuity and much desire to help other road users, for the owner to have fitted something which prevents the gases passing out horizontally and yet lets them get away easily without backpressure. Most of what is needed might be attainable if any horizontal exhaust pipe were bent downwards, but better if it could be bent upwards into a larger vertical pipe fully open at the top and having a small hole, say $\frac{3}{8}$in diameter, at its bottom end. (See Fig. 6.)

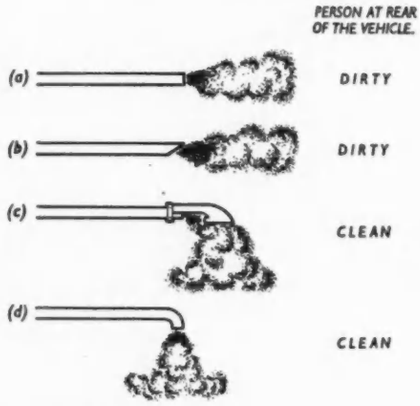
It is almost sure that where improvements have not been found by such modifications, wind tunnel tests have not been made, and it has been overlooked that there are upward and sideways air currents as a vehicle passes, as well as downdraughts. Correctly placed, most of the gases will pass upwards, diffuse, and be no nuisance ; because the vertical exhaust pipe may if need be curve to any desired position.

The answer to the above question, " Where are exhaust gases emitted?" is surely that steam locomotives, steam ships, diesel locomotives, diesel railcars, many tractors, U.D.C. refuse vehicles, army ambulances, power stations, houses and so on all emit their exhaust fumes in the direction in which they must eventually be dissipated—upwards. The one exception to this rule is the road motor vehicle that emits its exhaust into the faces of children on the pavements, on to my lady's nylons, on to my white flannel bags, to obscure the road ahead, to poison the passengers in following vehicles, and occasionally into the doorways of city tenements.

What Can be Done to Minimise This Growing Nuisance and Danger

Engineers, designers, traffic experts, and politicians cannot accept the present proved nuisance of low exhaust fumes from road vehicles as inevitable : it is clearly repugnant to our ideas of gracious living, courtesy, and good neighbourliness. We must, therefore, set about planning to eliminate the nuisance or at least to minimise it.

Large towns and cities now ventilate themselves with the aid of the heat from their buildings and road vehicles. Hot air rises naturally from the congested streets, even on windless days, and is replaced by cooler air that descends on the cooler green parks and



(*a*) Cut off square.
(*b*) Cut off diagonally.
(*c*) Provided with a clamped-on shell shaped accessory.
(*d*) Bent groundwards by the manufacturer.

Fig. 5—Exhaust exits types (*a*) and (*b*) are a nuisance to people and should be made illegal. Type (*c*) shows consideration by the owner and type (*d*) might well be adopted by more manufacturers

leafy squares. Were it not for some such natural turbulence the fumes from our vehicles would have concentrated near where they are emitted and the relatively heavy carbon dioxide, and the toxic carbon monoxide would have already killed the people on the narrow streets and in their nearby basements. We know that the fumes must be dissipated upwards ; that must be so because the fumes have not escaped through the roadway downwards, or through the buildings sideways, and so far the gases have not concentrated enough to suffocate the road- and basement-using people. So far we have been spared a road vehicle fume mass tragedy of the " Smog " type. The Smog deaths brought the great benefits of the Clean Air Act. Need we wait for road fume tragedies before taking drastic action to eliminate the low emission of internal combustion engine exhaust fumes?

The retention of the primitive low exhaust pipe is not an essential to motor vehicle sales. The usual steel exhaust pipes are so prone to corrosion and fracture due to vibration that it has been common to have to replace them every year in Australia, and they often fail in little longer than that in this country. Often before these underfloor pipes are seen to be perforated they have leaked exhaust fumes into the passenger compartment and people have suffered malaise as a result.

There is no reason to hope that some catalyst will be found that will eliminate all the constituents of motor exhaust fumes that will not support life. Hence we know that the gases and moisture emitted from the exhaust pipes will have to be eliminated by ventilation from our streets upwards, even if catalysts are used.

The case against vertical exhausts has never been proved. So far as is known no large order for vehicles has ever been placed in this country on the basis of serious experiment and serious instruction to design staffs in order to : emit the exhaust where it does not blow into third parties on the pavement ; disperse the exhaust upwards as it must eventually go that way ; decrease the local concentration of the exhaust fumes by surrounding them by a stream of the engine cooling air, passenger compartment ventilation air, engine blowback fumes, &c. ; make the funnel or chimney so functionally correct looking that in a short time people will wish to buy vehicles with that attractive type of chimney ; arrange the exhaust exit surround as in the Gresley Pacific locomotives to throw the fumes high with a stream of clean air under them at speed, trapping oil particles, preventing rain and snow troubling the vertical exhaust exit ; and finally, use the energy in the exhaust to induce the cooling air flow and the elimination of blowback fumes and vitiated air from the passenger compartment.

Should some clever design staff be given that task they would not increase the total amount of exhaust gases emitted so there is no reason to think that people at higher than street level need suffer from the change. If they are wise in their choice of materials they may well be able to reduce the present fire risks ; the annular exhaust of cooling air around the engine exhaust should certainly help to prevent fires.

We seem to have come to regard low exhausts as essential to road vehicles in order to keep up appearances or out of some odd respect for motor car tradition. Surely this feature requires the study of one of Lord Hailsham's self-reliant iconoclasts, inspired by efficiency, thoroughness, and a care for those on the pavement.

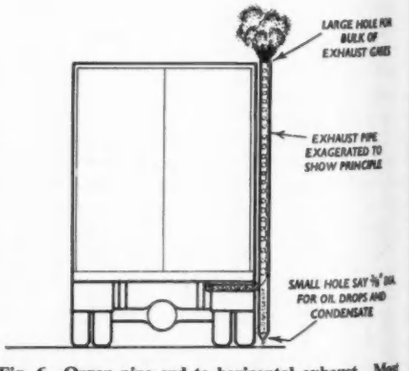

LARGE HOLE FOR BULK OF EXHAUST GASES
EXHAUST PIPE EXAGERATED TO SHOW PRINCIPLE
SMALL HOLE SAY ⅜" DIA. FOR OIL DROPS AND CONDENSATE

Fig. 6—Organ pipe end to horizontal exhaust. Most of the gases to pass unpwards, condensate to drip downwards. Pipe may be curved to emit gases where least trouble to all concerned, as found by wind tunnel experiments that include other road users

SHORTER REPORTS

Mechanical Engineering Conferences

A NUMBER of conferences have been organised by the Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1. An International conference held jointly with the A.S.M.E on "International Developments in Heat Transfer" is to take place in Boulder, Colorado, from Monday to Friday next and is to be repeated from January 8 to 12 next year. One hundred and twenty-four papers are included in the proceedings, under the following classifications: "Heat Conduction and Thermo-Electric Effects"; "Heat Transfer in Equipment"; "Boiling and Burnout Condensation and Two-Phase Flow"; "High-Speed Flows, Aspects of External Convection, Vibrations and Pulsating Flows"; "Internal and Duct Flow"; "Mass Transfer, Packed and Fluidised Beds"; "Radiation, Thermal Properties and Instrumentation," and "Free Convection." Four special lectures will be presented during the Boulder Conference: Professor Owen A. Saunders, City and Guilds College, London, immediate past-president of the Institution, will deliver a Calvin Rice lecture: "Some Reflection on Progress in Engineering Heat Transfer Science"; Dr. E. R. G. Eckert, University of Minnesota, will lecture on "Research during the last decade on Forced Convection Heat Transfer"; Dr. E. A. Schmidt, Munich, will speak on "Heat Transfer by Natural Convection"; while Dr. H. C. Hottel, Massachusetts Institute of Technology, will lecture on "Problems of Radiative Transport." It is intended to arrange for the re-presentation of these lectures at the London Conference.

The Hydraulic Plant and Machinery Group of the Institution is holding a conference at the Institution on November 29 and 30 on "Oil Hydraulic Power Transmission and Control." Twenty papers will be presented, and visits to works manufacturing hydraulic equipment are involved. The provisional allocation of subjects is as follows: "Pumps and Motors" (two papers); "Transmissions" (five papers); "Servos and Controls" (four papers); "Applications" (five papers); and seven miscellaneous papers.

Proposed Oil-fired Power Station at Fawley

THE Central Electricity Generating Board is applying to the Minister of Power and the local planning authority for consent to the establishment of an oil-burning power station at Fawley on Southampton Water. The proposed station would make use of reclaimed land and saltings between Fawley and Calshot and no part of the site would encroach on the modified boundaries of the Green Belt suggested by the Minister of Housing and Local Government.

It will be recalled that in December, 1960, the Generating Board gave its reasons for deferring a decision about seeking consent to build a nuclear power station at Hamstead on the Isle of Wight. The Board stated that it was investigating the alternative possibility of building a conventional power station on Southampton Water. The proposals for a Fawley power station are being made as a result of these investigations and if consent is obtained to such a station then consideration of the establishment of a nuclear power station at Hamstead on the Isle of Wight can be deferred.

The site at Fawley is suitable for a station of about 2000MW capacity. To meet the growing electricity demand in the south of England the first generating unit will be needed in 1967. The public demand for electricity in the southern counties is growing more rapidly than in the rest of England as a result of the high rate of industrial development and growth of population there.

Oil is the most economical fuel for electricity generation in this area and local generation using oil would not only supply electricity to the southern counties as cheaply as by generation in a remote coalfield station but also avoid long transmission lines from these remote areas to which there are objections both of amenity and cost.

It is proposed that the station should be connected to the national grid by an overhead 400kV line running northwards and by undersea cables to a line on the opposite side of Southampton Water. The routes of these lines have yet to be discussed with the local planning authority and interested bodies before applications for consent for them are made to the Minister of Power. The possibility of reducing the number of lower voltage lines on the west side of Southampton Water is being investigated.

With a clear and vigorous outline, and with careful attention to every aspect of design, the Board believes that the station could impressively mark the entry to Southampton Water and the end of its western industrial margin.

The Board states that its proposals for Fawley do not imply a change in policy regarding coal burning power stations. On the contrary the total coal consumption in C.E.G.B. power stations is expected to increase. It will be recalled that the Board has recently received statutory consent for a new 2000MW coal-fired station, Ferrybridge "C" in Yorkshire and is hoping for a favourable decision on the application for consent to another 2000MW coal-fired station at Eggbrough. Both these stations would draw their fuel from the same coalfield. The Board's statement points out that the recent rejection of its proposals for a 2000MW coal burning station at Home Pierrepont have made it necessary to consider alternative development to provide equivalent generating capacity.

National Radio Show

THE National Radio Show was opened at Earls Court, London, on August 23, and continues until 10 p.m. on September 2. Interest on the television manufacturers' stands centres largely on receivers completely equipped for 405-line or 625-line reception, with switch selection, apart from the addition of a plug-in u.h.f. tuner to be inserted later. Remote controls for channel-selection, and volume are also shown on several stands. The Dynatron "Space Selector," for example, is a small unit containing two spring-exciter tuning reeds emitting ultrasonic frequencies. The signals are picked up by a microphone behind the loudspeaker grille and amplified for control purposes. Volume can be adjusted in steps from a muted condition to full strength. Philco (Great Britain), Ltd. and Ekco Radio and Television, Ltd., show systems in which a light beam from a torch is directed on to an aperture at the front of the receiver, to excite a photocell controlling a motorised turret tuner. In the Philco system there are two apertures, one for channel selection and the other to switch the sound off or to return it to a pre-set level. Nearly 200 transistor receivers are assembled in a mass display. A pocket transistor set with m.f. and v.h.f. ranges is shown by Murphy Radio, Ltd. New components shown by Mullard, Ltd. include miniature carbon potentiometers for volume and tone controls in small battery radios and transistor sets, overall length being 9·7mm plus spindle length of 10mm, 15mm or 20mm as required. A new Mullard rectifier valve, PV33, has reduced anode/cathode spacing, achieved by using a "pressed powder" cathode which eliminates surface high spots.

Among the non-commercial exhibits, the Post Office tells the history of the telephone service in an effective display of showcases which are illuminated in sequence to the accompaniment of a recorded commentary.

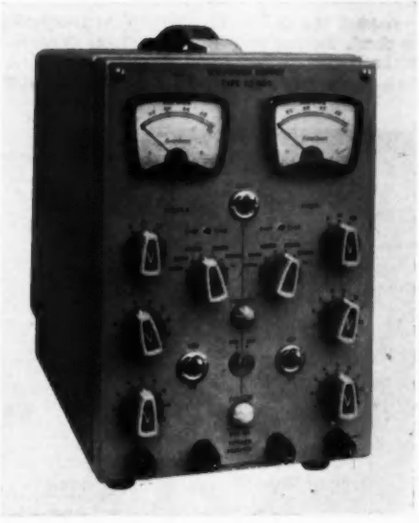
Maiden Voyage of S.S. "France"

THE French Line states that its Atlantic liner S.S. "France," which is being built at St. Nazaire by the Chantiers de l'Atlantique Penhoët-Loire, will commence trials as planned, and that the liner will begin her service with an inaugural cruise, sailing from Havre on January 19, 1962, and from Southampton on January 20. During the cruise to the Canary Islands a call will be made at Santa Cruz de Teneriffe, and the liner will return to Southampton and Havre on Saturday, January 27. The first sailing in the company's regular service from Havre and Southampton to New York will take place on February 3, 1962.

Power Supply for Transistor Circuits

To meet the needs of transistor circuit development, a twin-output power supply unit with adaptable characteristics has been introduced by Solartron Laboratory Instruments, Ltd., Cox Lane, Chessington, Surrey. The unit, Type AS 1164, comprises twin 0–30V "floating" supplies, each of 1A capacity. Outputs are independently adjustable in 0·17 increments by decade switching. They can be used separately as positive and negative supplies, switched into parallel operation to give 2A capacity, linked in series to provide a tapped 0–60V supply, or connected back-to-back to give 30–0–30V with either polarity. Each supply has separate overload limit selectors (25, 50, 100, 250, 500mA 1A) and current monitoring meters. A fully electronic proportional control system protects both the power unit and the circuit it supplies. Overload warning indicators are provided for each supply. In parallel operation there is one set of over-riding output level controls, but the current limit selectors remain operative and independent. This doubles the overload limit to 2A with finer intermediate settings. The unit which we illustrate weighs 25 lb and has dimensions $11\frac{3}{8}$in by $7\frac{5}{16}$in by $14\frac{5}{16}$in. Identical in shape and size with the Solartron R-C oscillator CO 1004·2 and pulse generator GO 1101, the power supply completes a group of laboratory instruments with many uses in circuit design, development and testing.

[Reply Card No. 1143]



Power unit with twin d.c. outputs usable in various combinations for circuit tests

SHORTER REPORTS *(Continued)*

Edge Register Control Equipment

In reeling materials on to mandrels, high speeds make it increasingly difficult to avoid "wandering" of the strip or web and, therefore, to maintain a clean edge on the complete reel. An edge register control equipment (Series ERC1) has been introduced by Lancashire Dynamo Electronic Products, Ltd., Rugeley, Staffs, to provide an economic means of controlling correction devices designed to position the edges of materials within close limits. The equipment comprises a photoelectric viewing unit through which the material passes, together with a remote wall-mounted control unit. Twin photocells observe the edge of the strip or web, the system being arranged so that one cell is obscured and the other illuminated when the position is correct. If the edge of the material moves, the direction of deviation is indicated by the photocell conditions and, after an adjustable delay period, the correction arrangements are initiated. After running for a predetermined time, the correction system is brought to rest and the equipment again checks the web position, repeating this operation until the edge of the material is restored to the correct location under the viewing head.

The Series ERC1 equipment includes provision for the adjustment of dead zone over a 4 : 1 range and is accurate to within $\pm 1/32$in when set up to optimum sensitivity. "Correction" and "Observe" time delays are adjustable from 0·3 to three seconds. Two viewing heads are available, with "throat" depths of 3in and 6in. The equipment is designed for 110V/115V or 200V/250V, 50/60 c/s single-phase supplies.

[Reply Card No. 1145]

Assessment of Engine Wear

Among the techniques used by oil companies to check the performance of products in service is the burning of droplets of used engine oil in an electric arc to make possible the detection of

Ultra violet emission spectrograph

abnormal wear rates in engines. To apply this technique a direct reading spectrograph is employed, and such an instrument is at present in service in the Central Laboratories at Egham, Surrey, of the Shell International Petroleum Company, Ltd. This equipment, of which we reproduce a photograph, is able to detect foreign substances in lubricants in concentrations as low as 1 p.p.m. and to do so in a short period of time. Excessive wear is indicated by the presence of metal, from the worn part, in the engine oil and the spectrograph facilitates the measurement of the rate of increase of this metal content in the oil. When the oil droplet is vaporised in the arc of the spectrograph, any metal atoms present became activated and in this state emit rays characteristic of the metals present, and these are recorded and measured electronically.

The instrument is automatic in operation, and on the control panel there are illuminated signals, each associated with a different metal. On pressing a button each signal is illuminated in turn and at the same time the quantity of metal designated by the signal is recorded on a dial. Provided that the selective system has been adjusted in advance, any metal can be traced and the amount recorded by meter. The spectrograph can store the information it produces and repeat it on demand, and also photograph it so that a record can be filed.

Clearance of Oil Contamination

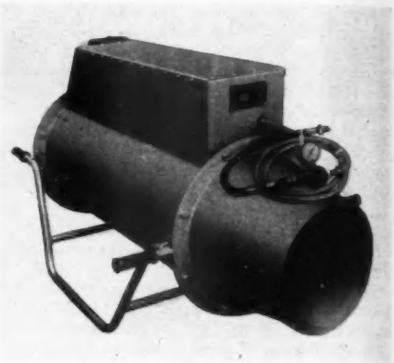
Measures taken to minimise contamination, and later to remove oil pollution, are recorded in a report issued by the Esso Petroleum Company, Ltd., relating to the two serious oil spillages with which the company had to deal in 1960. The first spill occurred during a fire in "Esso Portsmouth" at Milford Haven, and the second from the tanker "Bideford" at Fawley. At Milford Haven the methods used were manual cleaning, chemical cleaning and burning, and the types of pollution met during the cleaning-up operations were : floating pollution ; pollution on rocks and sea walls ; pollution in rock pools ; pollution on beaches ; pollution on mud flats ; pollution on reeds and grasses and contamination of boats. According to the report floating pollution ranged from heavy black contamination through floating slicks to areas where only slight refraction colours showed. A spill boom towed between launches corralled the heavy floating pollution where most of it could be removed by suction, and then straw was thrown on the residual oil to absorb it and was later burnt. Emulsifier sprayed from launches was used to remove any remaining oil, the turbulence caused by the passage of the launches being sufficient to effect emulsification so that dilution by sea-water effected eventual dispersion.

It is stated that in treating hard surfaces seaweed was first removed from rocks and burnt, and then emulsifiers were sprayed on to the cleared surfaces, and the resulting emulsion washed by water supplied at high pressure by fire pumps. Experiments to use a flame gun were dropped since a tarry deposit remained. For the treatment of rock pools the oil was first sprayed and the pool was then hosed out, and where this method was not possible, the untreated oil was hosed out and then treated as for floating pollution. Cleaning of shingle beaches proved to be difficult, but effective results were achieved by heavy spraying of emulsifier and then, after an interval for penetration and reaction, a water jet powerful enough to cut and turn over the shingle to a considerable depth was used, and the emulsion washed away into the sea where it dispersed. For mud flats the most successful treatment was found to be the spraying of an emulsifier in advance of the rising tide, so that tidal action would remove the emulsion. Vegetation such as reeds and grasses were cut and afterwards burnt, and then the exposed area was treated in the same manner as the mud flats, although washing by fire hose was more successful where the ground was firm. Emulsifier and white spirit were used for the decontamination of boats. The report records that in dealing with the task of decontamination it was found that speed in taking action is vital to prevent the spread of pollution, and also because the lighter fractions weather off the crude oil, leaving residuals which are more difficult to remove. Reeds and grasses proved not to be affected by the oil pollution or the removal treatment, but there was evidence that marine life had suffered.

Similar methods were generally employed for treating the spill of bunker oil at Fawley. However, on some beaches the continuous band of oil contamination was buried in a trench cut by bulldozers and subsequently back-filled, while in other places the whole beach was removed.

Mobile Air Heater

To facilitate the rapid drying out of new and renovated buildings the mobile air heater we illustrate has been developed by Woods of Colchester, Ltd., Colchester. It is so designed that air delivery can be either by direct discharge from the heater outlet or through an adaptor provided with single, two-, three- or four-duct outlets. The heated air is delivered at sufficient pressure to enable long lengths of flexible ducting to be employed and in certain circumstances the duct length can extend up to 390ft.



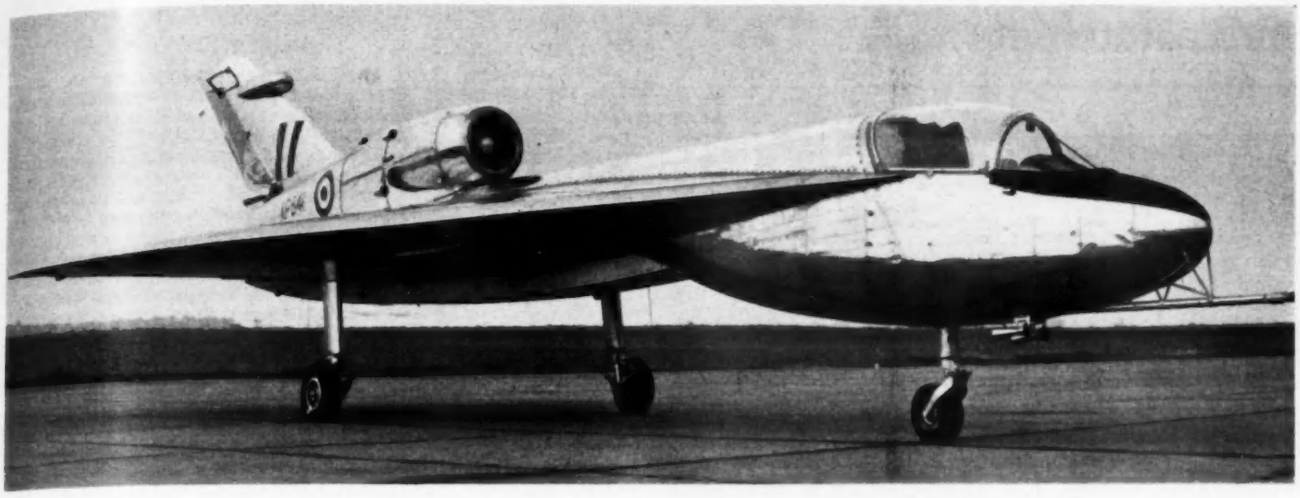
Propane-fired mobile air heater

The air-heating section of the equipment is direct-fired by propane and the heater only requires connecting to commercial propane bottles and the electricity supply. Its gas consumption at maximum output is 200 cubic feet per hour, and the nominal heat output is 500,000 B.th.U. per hour. Performance figures vary depending on the air flow—a 100 deg. Fah. increase in air temperature can be achieved with a flow of 4000 cubic feet per minute, while with the airflow at 6000 cubic feet per minute the temperature rise is 75 deg. Fah.

[Reply Card No. 1148]

Heating, Ventilating and Air Conditioning Exhibition

The first International Heating, Ventilating and Air Conditioning Exhibition will be held at Olympia, London, from Tuesday, September 26 until Friday, October 6. This exhibition is organised by Industrial Exhibitions, Ltd., promoted by an advisory committee from the industry, and sponsored by The Institution of Heating and Ventilating Engineers. During the exhibition, which will be officially opened at 11.30 a.m. on Tuesday, September 26, by Mr. C. J. Atkins, the chairman of the "Hevac" Exhibition advisory committee, there will be an international conference in the Empire Hall from September 27 to October 4.



The H.P.115 has the most heavily swept leading edge of any aircraft yet flown ; the fin and rudder are also swept

Slender Delta Research Aircraft

THE first flight has now taken place of the H.P.115 research aircraft, a small low-speed aeroplane built to investigate the handling qualities of extremely low aspect ratio configurations which are attractive for their low drag in a supersonic cruise. The H.P.115 is 45ft long and has a span of 20ft ; the wing tips are slightly squared, so that the aspect ratio is close to 0·5. One of the characteristics of these heavily swept aircraft that fly in the fully separated regime is that they are insensitive to Reynolds number (since viscosity acts by affecting the extent of separation) and hence the experimental aircraft should provide information applicable to far larger and heavier machines.

The accompanying photograph shows the sharp leading edge ; while the leading edge itself may be set slightly downward relative to the chord line, the appearance of camber is an illusion due to the differing aspects of upper and lower surfaces. Below the wing a large perforated air brake can be seen slightly open ; there appears to be an extremely slab-sided centre section projecting below the wing. Other details of interest are the heavily swept rudder, the design of the balance mass of which suggests that extreme travel is needed (in, presumably, the exaggeratedly nose-up approach attitude) and the duplicated Venturi tubes to generate speed signals at rather low dynamic pressures. The undercarriage on the experimental machine is fixed, but nevertheless conveys some idea of the great extent necessary for landing gear or machines of high fineness ratio.

The H.P.115 is powered by a Bristol Siddeley "Viper" 9 of 1900 lb thrust : this engine is of some interest in that a pair of Armstrong Siddeley "Viper" 9 engines powered the Bell X-14 at the time when it was the only jet (or fan) v.t.o.l. aircraft to have flown.

The first flight of the H.P.115 was made on August 17 from the airfield at the Royal Aircraft Establishment, Bedford, and lasted thirty-one minutes ; it is recorded that the machine functioned perfectly.

Pressure-Assisted Relay Contacts

IMPROVEMENTS are announced in the load-current-contact-aiding (LCCA) relays manufactured by Daystrom, Ltd., Bristol Road, Gloucester. In the normal pattern an additional locking winding on the moving coil is placed in series with the load when the contacts are closed, the load current through the locking winding producing a pressure of one to three grammes. The new version, known as "MagTrak," adds a soft iron bead to the moving pointer and a permanent bar magnet assembly on each adjustable index arm, to assist reliability at low switching voltages by greatly increasing initial contact pressure. When the pointer reaches the control point, the permanent magnet pulls in the pointer and moving contact against the flexible index arm with a rapid action which breaks high-resistance films and reduces transient arcing. This principle has been applied in the Model 1073 "MagTrak" relay. Here the "MagTrak" feature provides the initial pressure required to break built-up films, and the locking winding on the moving coil then comes into operation as described above. For resetting the relay, a push-button switch on the front of the case is operated. This breaks the current through the locking winding, allowing the compressed flexible contact to kick away the moving contact with sufficient force to override the permanent magnet. The "MagTrak" principle will be applied in future to all standard Weston load-current contact-aiding relays.

[Reply Card No. 1146]

Remote Data Processing

TRANSMISSION of data and of processed information between an office in London and a computer at Harlow, Essex, was demonstrated last week by Standard Telephones and Cables, Ltd., Connaught House, Aldwych, London, W.C.2. The system operated over a leased four-wire telephone line using separate pairs for out and return signals. Data for processing by the "Stantec" computer at the Standard Telecommunications Laboratories, Harlow, was punched in the five-unit "Zebra" code on paper tape and passed to an Elliott tape reader operating at 147 characters per second. The tape reader output was fed into logic circuits which accepted it in parallel mode and converted it into serial mode with two added bits per character to provide a simple form of parity error detection. This seven-unit code input then passed to a T1J transistorised terminal equipment where the positive and negative d.c. signals produced frequency modulation of a carrier having a centre frequency of 1800 c/s to give a v.f. output with a frequency shift of 480 c/s. Transmission speed was approximately 1000 bauds. As seen in the illustration below, ordinary telephone apparatus was provided over the same line for use in establishing connections.

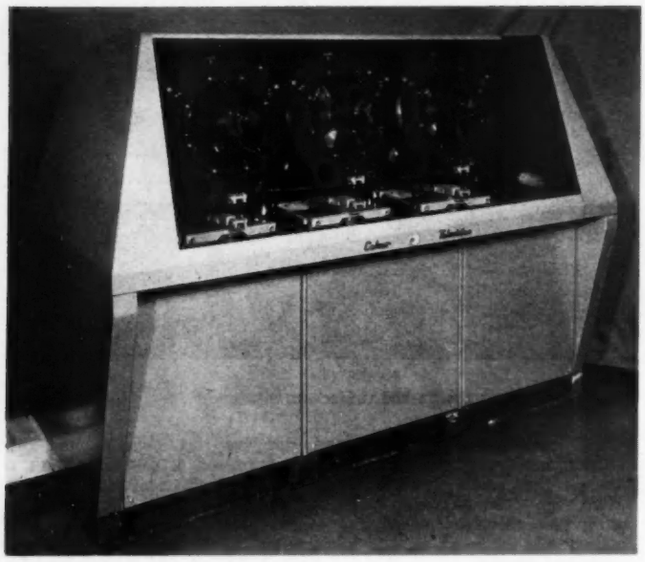
At the computer station, characters were checked, reconverted to parallel mode and passed to the computer for processing according to a programme selected by a code punched on the data tape. Processed information was sent back at 50 bauds. The output from the demodulator operated a relay controlling a Creed 75 teleprinter.

The "modem" (modulator/demodulator) unit used in the demonstration is built up of units assembled in a mounting case 8¾in high by 7¾in deep by 20in wide, and can be supplied for operation on 95–255V, 45–65 c/s. Power consumption is approximately 40VA. Logic equipment can be housed in a pedestal of a desk such as the one illustrated. It was emphasised at the demonstration that its purpose was to illustrate principles rather than to show a fully elaborated system. For example, a wide range of modulation rates is possible, and various rates might be used in different parts of a larger network linking numerous outstations to a computing centre. Transmission of data can take place over the inland public telephone network at speeds of the order of 600 bits a second, while speech-quality private circuits may be used for speeds up to 2000 bits a second in favourable conditions. These services were announced by the Post Office in May this year as part of its current programme of co-operation with users and manufacturers of computers and automatic data processing equipment.

[Reply Card No. 1150]

Data transmission and receiving equipment for use with a remote computer, showing tape reader, modulator / demodulator (left background) on teleprinter on which the processed data are received

SHORTER REPORTS *(Continued)*



Projector for colour television, showing the cathode ray tubes and optical systems for the red, green and blue components

Colour Television Projector

THE colour television laboratories of Marconi's Wireless Telegraph Company, Ltd., Chelmsford, have recently completed development of a new large-screen projector for colour television. The projector accepts either separate red, green and blue signals, or a composite coded signal, and projects a picture measuring 12ft by 9ft on to a screen 25ft away. Each colour channel has a separate video amplifier with a bandwidth of 10 Mc/s. The amplifiers feed 5in cathode-ray tube projectors operating at 50kV e.h.t., in which the tubes, specially designed by The English Electric Valve Company, Ltd., are associated with Schmidt in-line optical systems. Each system consists of a concave glass reflector with an aspherical glass corrector plate which focuses the picture in a flat plane. The three projectors are mounted side by side, only the centre one being on the normal to the screen. An electronic correction waveform has therefore to be applied to each outer cathode-ray tube to avoid "keystone" distortions of the picture.

The equipment has been designed for long-term stability and reliability, with continuous operation for twenty-four hours a day as an essential capability. Once set up, the only controls that need to be used are brightness, focus and contrast for the system as a whole, all other adjustments being preset.

[Reply Card No. 1142]

High Gain Image Intensifiers

DEVELOPMENT is in hand by The English Electric Valve Company, Ltd. of a high gain image intensifier tube required by the U.K.A.E.A. at Harwell, mainly for viewing the output of scintillation detectors. These include fibre scintillation chambers where the amount of light arriving at the detector from each scintillation is measured in tens of photons. Under such conditions the ability of the tube to detect better than one photon in ten is of fundamental importance.

The English Electric high gain image intensifier tube comprises an input photo-cathode, five secondary emitting dynodes and an output fluorescent screen, and is operated in conjunction with a focusing solenoid, input and output optical systems and power supplies. The image to be intensified is focused on the photo-cathode at one end of the tube, and the photoelectrons are accelerated and focused on to the first thin film dynode. Secondary electrons, five or six to each primary, are emitted from the other side of the dynode and these are in turn accelerated and focused on to the second dynode. This process is repeated at each dynode, and the secondaries emitted from the final dynode are accelerated on to a fluorescent screen to produce an intensified replica of the original weak light image. The process differs from electron multiplication in the ordinary photomultiplier in that there is no random emission of electrons, but at each stage there is a fixed relationship between the electrons focused on to a thin film dynode and those emitted from the other side. Tubes have been made giving a photon gain of 100,000 to 200,000, in which a gain of 7000 is provided by the five stages of secondary electron multiplication, the remainder arising from the bombardment of the output fluorescent screen. The usable diameter of the thin film dynodes is 1in. If desired, the picture may be reduced in size between the photo-cathode and the first dynode, so that the diameter of the input picture need not be limited to 1in. Similarly a larger picture may be formed on the screen if required.

[Reply Card No. 1140]

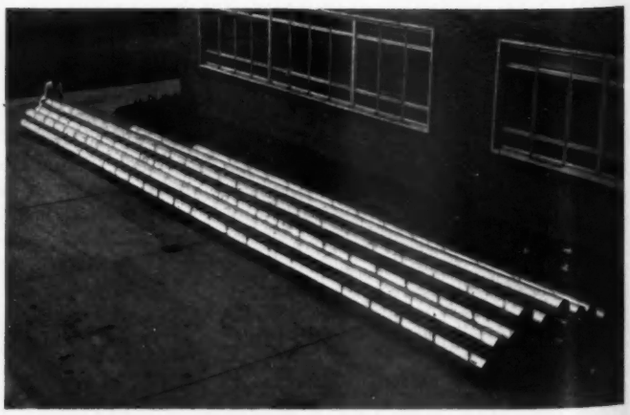
Helical-Weld Aluminium Pipe

UNTIL recently the two main forms of aluminium tubing available in quantity were extruded and drawn seamless tube and were limited to a maximum diameter of about 12in by practical considerations. However, due to the successful adaptation of the helical-weld method of tube-making to aluminium, large scale production of aluminium pipe up to 28in diameter is now possible. The method of rolling plates into cylindrical shape, and then completing the fabrication of the pipe by a longitudinal weld, does not lend itself to large-scale production of large diameter pipe.

The helical-weld method consists of feeding metal strip into formers or a series of rollers set at an angle so that the strip describes a helix as it travels through the machine. The resulting helical seam is then welded continuously and automatically to produce tubing in long lengths and to accurate limits. First developed for steel pipe at the end of the last century, it took many years of improvements in strip quality, in automatic welding techniques and particularly in continuous weld testing and quality control, before the process produced consistently high quality helical-welds (see pages 110 and 122, Aug. 21, 1959). Because of the increasing demand for thin-walled large diameter aluminium pipe Alcan Industries, Ltd., in collaboration with the makers of helical-weld equipment, undertook a development programme for the production of helical-weld aluminium tube. An important factor contributing to the success in making tube of consistently high quality was the close tolerances to which aluminium strip is supplied, which ensured excellent edge matching conditions for welding purposes. Welding speeds are higher with aluminium than with steel, so that a higher rate of output is possible and manufacturing costs are lower. Helical-weld tubing, examples of which can be seen in our illustration, is now available in sizes from 6in to 28in diameter, from Apitubes, Ltd., Bristol Aerojet, Ltd., and The British Steel Piling Company, Ltd., while at Oberhausen, near Dusseldorf, Intercontinental Enterprises, G.m.b.H., are building a "Heliweld" plant capable of forming tube up to 120in diameter from strip up to ½in thick.

Trawler Machinery Maintenance

THE six middle water trawlers which are being built by T. Mitchison, Ltd., for the Pelagic Trawling Company, Ltd., are of hydroconic hull form and are each powered by two Bristol Siddeley Maybach MD. 225 high-speed diesel engines having a total output of 788 b.h.p. These engines drive a controllable pitch propeller through a Hindmarch-MW.D. gearbox. When requiring an engine overhaul a trawler can be held in port from eight to ten days, but to obviate the amount of time lost and the expense incurred, it has been decided to adopt maintenance by replacement. One of the factors influencing the decision is the comparatively small size and light weight of the Bristol Siddeley-Maybach units so that instead of operations taking place in the engine-room, complete engines can be lifted out and replaced by spares in twelve hours. A life of at least 16,000 hours between overhauls can be expected: to reduce maintenance costs incurred through excessive wear caused by manoeuvring requirements when fishing is the reason for fitting a controllable pitch propeller—this enables the engine to run at constant speed. In order to operate the system efficiently there will be three engines, additional to the twelve installed on board, kept on shore ready to replace a unit requiring overhaul.

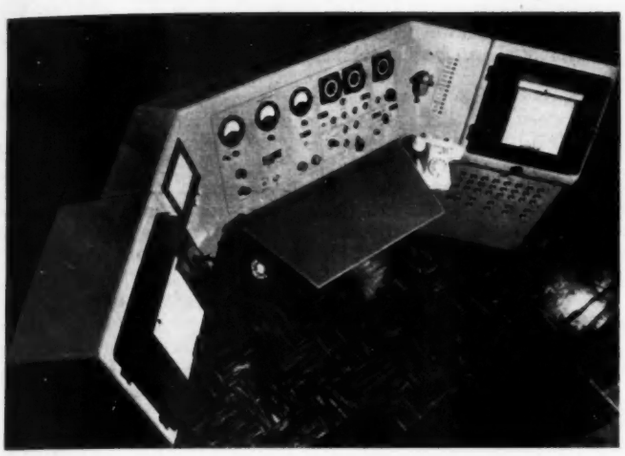


Large diameter, thin-wall, helical - weld aluminium pipes

Control Desk for Materials Testing Reactor at Dounreay

THE photograph reproduced here shows a new control console which has recently been installed in the Materials Testing Reactor (D.M.T.R.) at the Dounreay establishment of the United Kingdom Atomic Energy Authority at Dounreay. This control desk was designed and manufactured by James Scott (Electronic Engineering), Ltd., 68, Brockville Street, Glasgow, E.2, in collaboration with the D.M.T.R. staffs responsible for the instrumentation and operation of the reactor. The console is arranged to contain all the controls for starting-up and shutting-down the reactor and for the main operational parameters.

In the central panel there are push buttons for reactor start-up, signalling, shut-down, scram-signalling and alarm, together with reactor control arm position indicators and controls. The display also includes meters showing important reactor parameters. The left-hand pedestal houses a large recorder for indicating heavy-water differential temperature, and a twenty-four-way annunciator panel. The right-hand pedestal houses the ion-chamber recorder for indicating reactor power and the controls for a public address system.



Control desk for Materials Testing Reactor at Dounreay

The alarm annunciator system is capable of indicating fault conditions at up to twenty-four stations on the reactor. A fault condition is arranged to close a switch which energises an appropriate relay in the annunciator. When the fault is registered an indicating lamp, which is normally just glowing, intermittently flashes on full brilliance. The controller can decide whether to ignore or accept the fault by depressing a push button. When the fault is accepted the indicating lamp remains at steady brilliance.

[Reply Card No. 1151]

Museum Exchange Radio Tower

FURTHER details were given last week of the extensions and microwave radio tower to be built at the Museum telephone exchange, London (THE ENGINEER, February 10, 1961, page 218). This exchange is already a national communications centre for telephony, broadcasting and television links, both by cable and radio. Pressure on existing channels, combined with the cost and difficulty of providing additional cable routes in built-up areas, have made it necessary to carry more traffic on microwaves. These require line-of-sight paths, and since existing paths are already being threatened with obstruction by higher buildings in the London area, the decision was taken by the Post Office to place existing aerials and those for new services on a tower over 500ft in height. This is to be accompanied by a new building providing approximately 150,000 square feet of floor space, mainly for accommodation of automatic telephone equipment. The building has been designed as an extension of the present Museum exchange, and will occupy the whole of the new site area adjoining the existing exchange, except the part occupied by the tower and its associated service yard. Work has begun on the foundations of the building, which are being constructed by Peter Lind and Co., Ltd.

Speaking at a press conference on August 16, Mr. Richard Thompson, Parliamentary Secretary to the Ministry of Works, said that the Ministry tended to be regarded by the public as a custodian of ancient monuments, but the present project showed that they were " builders for to-morrow " as well. The tower itself would begin to rise next year, and they expected to have it completed in 1963.

The tower will be slim for its height—only approximately 54ft in diameter—and will be mainly of glass and concrete. It will have a hollow central shaft of reinforced concrete 2ft thick and 31ft internal diameter at the bottom, tapering to 20ft internal diameter with 12in thick walls near the top. As well as providing the " spine " of the tower, the shaft will also contain the lifts, ventilation ducts, Post Office cables and all other services. As seen in the accompanying sketch, it will be surmounted by a 45ft lattice mast which could be used for additional aerials, or might enable line-of-sight paths to be maintained if those from the lower aerials became obstructed by other buildings, although this is considered unlikely. Thirty reinforced concrete cantilever floors will branch from the central shaft of the tower. Two high-speed lifts, operating at 600ft per minute, will convey the public to the restaurant, the tea and snack bar, and the observation platforms. Part of the restaurant floor will be a circular platform 8ft wide, which will revolve at a speed of one revolution in half an hour to provide a changing panoramic view over London.

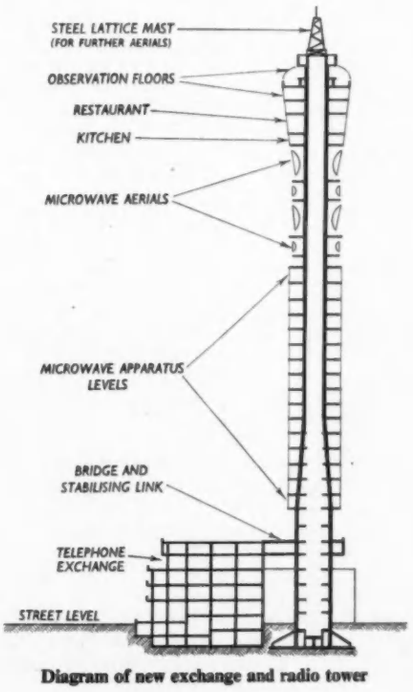


Diagram of new exchange and radio tower

The tower has been designed for the General Post Office by the Chief Architect's Division, Ministry of Works. Stability of the tower is assisted by the bridge deck connecting with the main building at 80ft above the ground. The deck transmits a maximum horizontal wind force of 500 tons, and the structure of the adjacent main building is stiffened to provide this restraint. Use is made of the bridge as a cable entry for the tower apparatus. The attachment of the tower to the deck is arranged so as to provide a lateral stay without resisting vertical deformation relative to the main building. Main stability of the structure is provided by an internal hollow r.c. shaft, tapering from 35ft to 22ft diameter. This shaft will contain the high speed-lifts, the ventilation ducting and the service cables to the equipment.

In the lowest section of the tower, rising 115ft above ground level, the shaft is provided with internal stiffening rings. This section will have an exposed aggregate finish. The next section, from 115ft to 355ft above ground, provides seventeen floors. The lower three floors contain the high-velocity ventilation plant for the radio equipment, while the remainder will house the microwave apparatus itself. This section of the tower is enclosed with glass cladding. Windows will be double-glazed, with fixed outer panes cleaned externally from power-operated cradles running in bronze guides. When not in use, the cradles will be housed in a recess near the top of the tower. Venetian blinds are arranged between the glazing.

The third section of the tower will house the platforms for the main aerials, and these will be unclad to minimise interference with transmission. Waveguide controls will be housed in an intervening set-back floor. Above the fourth section containing the public restaurant and observation floors, the main shaft rises a further 31ft and houses the lift motor rooms and control gear. Surmounting the concrete shaft will be the lattice tower for additional aerials.

Launches and Trial Trips

ADMIRAL BURNETT, trawler ; built by Hall, Russell and Co., Ltd. for Parbel-Smith, Ltd.; length overall 152ft 9in, breadth moulded 28ft, depth moulded 14ft, fish-room 10,500 cubic feet, electric trawl winch, two 35kW diesel-driven generators ; Mirrlees, seven-cylinder turbo-charged four-stroke diesel engine, 1022 b.h.p. Trial, July 5.

DANIELA, coaster ; built Ateliers et Chantiers du Rhin for Somefin Company (Israel) ; length between perpendiculars 225ft 1in, breadth moulded 36ft 5in, depth to shelter deck 22ft, draught 12ft 8in (open shelter) 15ft 9in (closed shelter), dead weight 1000 tons (open shelter) ; trial speed 13 knots ; Sulzer turbo-charged diesel engine, 1560 h.p. at 300 r.p.m. Trial, June.

ESSO LORRAINE, oil tanker ; built by Chantiers de l'Atlantique for Société Anonyme Esso Standard ; length between perpendiculars 707ft, breadth moulded 102ft 3in, depth 50ft 5in, draught loaded 38ft 9½in, deadweight 48,000 tons, speed 16·8 knots ; one set of geared C.E.M.-Parsons turbines, 17,500/19,250 s.h.p.; steam supplied by two P.41 Penhoët boilers at 850 lb per square inch and 860 deg. Fah. Trial, June.

ILESHA PALM, cargo ship ; built at the Neptune works of Swan, Hunter and Wigham Richardson, Ltd., for the Palm Line, Ltd.; length between perpendiculars 430ft, breadth moulded 62ft 6in, depth moulded to shelter deck 36ft 11in, dead weight 8800 tons on 25ft 0½in draught ; three bipod masts, five holds, one 50-ton, four 15-ton, two 10-ton and ten 5-ton derricks ; three 250kW diesel-driven generators ; Swan, Hunter-Doxford four-cylinder oil engine, 4500 b.h.p. at 118 r.p. Launch, June 28.

ANN M, coaster ; built by The Burntisland Shipbuilding Company, Ltd., for Metcalfe Motor Coasters Ltd.; length between perpendiculars 218ft, breadth moulded 36ft, depth moulded 15ft to upper deck, and 19ft to raised quarter deck, draught 14ft 6in, deadweight 1620 tons ; three holds, MacGregor hatch covers ; two 30kW diesel-driven generators and one 16kW propeller shaft-driven generator ; two Lister-Blackstone eight-cylinder diesel engines each rated at 660 b.h.p. at 750 r.p.m. drive a single propeller at 250 r.p.m. through a twin input, single output Hindmarsh/Modern Wheel Drive reverse/reduction gearbox. Launch, June 12.

INDUSTRIAL NEWS

T.U.C. Report

The Report of the General Council of the Trades Union Congress, has now been published, and will be presented to the ninety-third annual congress, to be held at Portsmouth on September 4 to 8. It is a document of about 200 pages, and records in detail the great variety of matters brought before the Council during the year. Eight cases of inter-union dispute were heard under the disputes machinery of Congress, and the question of co-operation between unions was discussed, together with numerous matters of internal organisation. Representatives of Congress served on a committee set up by the Minister of Labour to inquire into the various Truck Acts and this committee reported in July, 1961, recommending that existing legislation should be replaced by new legal provisions adapted to modern conditions.

Information has been collected on the causes of strikes and the report says that "... very few of the 200,000 stewards ... misuse their office." It adds, however, that " Because of this few " attention is called to the fact that stewards are union officers and are bound by the rules. It advises greater vigilance and the withdrawal of a steward's credentials if, after a warning, he repeats actions contrary to rules. Some form of disciplinary action is called for where strikes are caused or prolonged, contrary to general policy. This disciplinary action can include expulsion of a member from his union, and the report on which the Council's action is based says that, when a union decides on expulsion, it is unlikely that another union would give the ex-member further opportunities to do harm. It is pointed out, however, that this does not mean that a union representative expelled for unconstitutional conduct would be ineligible for membership of any other union. It means that other unions concerned should be watchful that he did not obtain opportunities to repeat his wrong leadership.

In the social insurance and industrial welfare field the Council has recorded its view that compliance with the provisions of the Factories Acts is poor, and has called for augmentation of the factory inspectorate with the immediate aim of ensuring that every factory is visited at least once in every two years, and the long-term aim of an inspectorate of sufficient size to implement the 1926 International Labour recommendation of annual visits.

The Council made representations to the Chancellor of the Exchequer prior to the 1961 Budget, and subsequently issued a statement showing its disapproval of the surtax concessions and the proposed payroll tax. A meeting of representatives of the Council with the Chancellor followed, and urged him and the Government to take action to stimulate investment and growth "... where it was most desirable, and by the selective use of controls and incentives reduce to a minimum any balance of payments risk which this might involve." In July the Council again reviewed economic developments and, following the special economic measures introduced by the Government towards the end of that month, issued a further statement. It expressed surprise that the Chancellor should propose a pause in wage increases, and stated that wages had been rising less rapidly in Britain than in most other European countries, citing Germany as an example, where, it said, wages had been going up twice as quickly. The Council noted with interest the statement by the Chancellor that he intends to discuss with both sides of industry the question of setting targets for planned increases of output, and added that planned growth is only possible if both sides of industry are convinced that it is worth while for the improved standards of living it can bring. The Council added that if the Government is willing to give a positive lead, it will readily take part in a collective examination of how the country's great potential can be harnessed more effectively.

In the matter of public ownership of industry the T.U.C. again affirmed its belief in the principle, and during the period under review examined proposals relating to several sections of the engineering industry, including shipbuilding, railway locomotive and rolling stock manufacture, and aircraft and machine tool building.

Safety in Mines

THE report of H.M. Chief Inspector of Mines and Quarries for 1960, which has just been published (H.M.S.O., 4s.) shows that, making allowance for the fact that the number of manshifts worked in 1960 was appreciably less than in 1959, there was no improvement in the rate for persons killed in the period under review and that in the rate for persons seriously injured there was a deterioration. The Chief Inspector says that over the last ten years there has been little or no improvement, and that this condition of stalemate is a matter of serious concern. He adds, " In the opinion of the Inspectors, who investigate every serious accident, at least half those occurring every year could be avoided by compliance with the law, or by the exercise of ordinary care."

At the end of the year 808 coal mines were being worked by the National Coal Board and 420 small mines were operated by private owners under licence from the Board, making a total of 1228 mines in use. H.M. Inspectors made a total of 26,573 inspections during the year, 16,680 underground and 9,893 on the surface.

Accidents with explosives were in the main caused by contravention of the law ; usually they were the result of the injured person taking inadequate shelter, or of the shotfirer failing to determine the extent of the danger area accurately. In accidents arising from mechanical engineering causes the total was the lowest ever recorded under this heading. There is, however, no reason for complacency in this connection, as a detailed study of the accidents shows that very little has been done to make haulage and transport any safer. This applies equally to quarrying, where the number of accidents increased in the year under review, largely in haulage and transport operations. Some promise of improvement in quarrying appears in the advent of machines with specially designed hard teeth, which can be used to rip hard sedimentary rocks in a horizontal plane. Previously, only soft deposits could be ripped in this way. This kind of ripping produces what is, in effect, a horizontal face, which should be safer to work.

Coal mine fires continue to be a cause for concern. There were seventy-six in 1960, compared with seventy-one in 1959. Every fire, however small, has the potential of developing into a major disaster, and it is particularly important to note that many of the fires reported could have been prevented by better maintenance. Electrical fires, for example, included four involving drill cables, and in three of them the protective devices were faulty. Mechanical friction was another cause of fire, and the report notes that some of these fires would not have occurred if care had been taken to lubricate the machinery correctly, or to keep inflammable material away from moving parts. One fire caused by a locomotive disclosed the fact that the engine was filthy and a gasket had blown, leaving a gap through which hot gases blew on a deposit of oil and coal dust on the engine. Better standards of installation and maintenance would do much not only to reduce the number of fires, but to prevent accidents of all kinds.

Ionising Radiations Regulations.

The Minister of Labour has made, under the powers conferred on him by the Factories Acts, special regulations relating to the use of materials capable of producing ionising radiations. The regulations, which came into force on August 15, have been published under the title " The Ionising Radiations (sealed Sources) Regulations, 1961 " (H.M.S.O., 9d.) They apply to all factories (and all other premises to which Part IV of the Factories Act, 1937 applies with respect to special regulations for safety and health) in which any sealed source, machine or apparatus capable of producing ionising radiations is used or proposed to be used. There are certain exemptions, as for instance, X-ray apparatus used in rooms specially set aside for the purpose, and certain nuclear installations.

Subject to these exemptions it is now necessary to advise the local factory inspector of the use of the specified apparatus ; also if it is taken out of use, notification must be given. There are detailed provisions regulating the employment of persons about the apparatus, arrangements for protecting workers, measurement of radiation, handling of sealed sources, breakage, storage and registration of sealed sources. Provision is also made for health tests on employees, medical examination and recording and other safety precautions.

Laid-Up Shipping

ON July 1, British vessels laid up in home ports through lack of employment totalled forty-seven ships of 327,797 tons gross, which included thirty-two oil tankers of 279,395 tons gross, compared with seventy-seven ships of 480,458 tons at the beginning of the year and ninety-nine ships of 744,974 tons one year ago. World shipping laid-up at the beginning of July amounted to 363 ships of 3,195,460 tons gross of which included fifty-six British ships of 437,186 tons gross, the comparative figures on July 1, 1960, being 663 ships of 5,471,179 tons and, 111 ships of 909,137 tons gross respectively.

PERSONAL AND BUSINESS

Appointments

COLONEL DONALD CAMERON, of Lochiel, has been re-appointed to be a part-time member of the British Transport Commission until August 31, 1962.

MR. JOHN BLINCH has joined the board of directors of Industrial Education International, Ltd., and its associated company Materials Management International, Ltd., and will be responsible for the work of these two organisations in Europe.

MR. H. JOHNSON AND MR. H. B. TRAVIS have joined Suffolk Iron Foundry (1920), Ltd., as area technical representatives. Mr. Johnson's area will be Lancashire and the north-west coast, and Mr. Travis will operate in Yorkshire and the north-east coast area.

THE BRITISH BROADCASTING CORPORATION announces the appointment of Mr. A. H. Hill, M.A., as engineer-in-charge (Television), Birmingham, in succession to Mr. J. D. MacEwan, B.Sc., A.M.I.E.E., A.M.Brit.I.R.E., who has been appointed regional engineer, Northern Ireland.

MR. J. P. CLIFTON, manager, Technical Manuals Department, Witton, Birmingham, of the General Electric Company, Ltd., retired at the end of July after twenty-six years service with the company. Mr. Clifton will continue to serve in a consultative capacity until the end of September.

Mr. D. R. MACKIE, managing director of Monsanto Chemicals, Ltd., is resigning his position, following an illness. His resignation takes effect from October 1, but he will remain a member of the board. Mr. Mackie will be succeeded as managing director by Mr. John C. Garrels, Jnr., deputy managing director.

MERZ AND MCLELLAN announces that Mr. James Robert Beard will be retiring from the partnership on December 31, 1961, but has agreed to continue his association with the firm as a consultant. From January 1, 1962, Mr. Alan Edgar Powell will act as senior partner. He will normally be based at the firm's office at Milburn, Esher, Surrey.

THE RT. HON. LORD BRABAZON OF TARA, G.B.E., P.C., M.C., F.R.Ae.S., has accepted the invitation of the Minister of Aviation, Mr. Peter Throneycroft, to become chairman of the Air Safety Board. Lord Brabazon succeeds Air Marshal Sir Charles Guest, K.B.E., C.B., who has retired from his appointment as chief aeronautical adviser to the Minister.

AIR MARSHAL SIR COLIN W. WEEDON, K.B.E., M.A.(Cantab.), M.I.Mech.E., A.F.R.Ae.S., R.A.F. (Retd.) has asked Rolls-Royce, Ltd., to accept his resignation from his present duties as director and general manager, commercial sales, Aero Engine Division, and the company has agreed to his request with regret. Sir Colin will remain with the company as senior Aero Engine Division representative.

THE PERKINS GROUP announces four new appointments. Mr. T. H. R. Perkins becomes assistant managing director and continues to hold his position of marketing director of the Group. Mr. D. F. W. McNair has been appointed deputy director of marketing; Mr. J. M. Collins becomes general manager of the Group's sales division; and Mr. H. Lymath succeeds Mr. McNair as group project co-ordinator.

EIMCO (GREAT BRITAIN), Ltd., announces the appointment of Mr. A. R. Hilton as mining projects engineer. He will advise on the application of Eimco machines for mining and civil engineering and will also be responsible for investigating requirements for, and development of, new equipment for coal mining. Mr. Hilton was previously Eimco technical representative in Lancashire and the West Midlands, and he is being succeeded in this post by Mr. A. Whitworth, formerly an under-manager for the N.C.B.

SIR PHILIP WARTER, who is at present a part-time member of the British Transport Commission, has been appointed to be Deputy Chairman of the British Transport Commission as from October 1, in succession to Sir John Benstead. The Minister of Transport has decided to appoint Mr. P. H. Shirley and Mr. L. H. Williams to be full-time members of the Commission, Mr. Shirley as from October 1 and Mr. Williams as from September 1. Mr. Shirley will have a special responsibility for finance, and Mr. Williams for commercial affairs.

THE MOSS GEAR COMPANY, Ltd., announces that Mr. J. R. Hudson, joint managing director, retired at the end of July, after forty-three years' service with the company. Mr. E. Cars, previously works director, becomes joint managing director, and the board is being strengthened by the appointment of Mr. J. T. Riley as works director; Mr. Riley retires from the board of David Brown Industries, Ltd., to take up his new appointment. Mr. S. L. Duckitt, chairman, and Mr. A. W. Macferson, sales director, retain their previous positions on the Moss Gear board.

Business Announcements

EKCO PLASTICS, Ltd., is moving its London offices from 5, Vigo Street, W.1, to larger premises at 41-47, Old Street, E.C.1. The new address will be effective from August 28.

THE BOLTON GATE COMPANY, Ltd., has been appointed United Kingdom selling agents for the electro-mechanical door operating gear made by Helmut Heinz Bunzl, of Zurich, Switzerland.

J. H. FENNER AND CO., Ltd., announces that its Glasgow branch is now equipped with Telex. The number is 77269. This extends the Telex facilities already at the company's Hull, Birmingham, London and Manchester premises.

U.S. INDUSTRIES INC. (GREAT BRITAIN), Ltd., 1-5, New Bond Street, London, W.1. announces that the "TransfeRobot" (described in THE ENGINEER, August 4, 1961, page 218) is now available in this country and is to be manufactured at the works of Burtonwood Engineering, Ltd., Warrington, Lancs.

THE PLESSEY COMPANY, Ltd., and the PHILCO CORPORATION OF PHILADELPHIA have issued a joint statement to the effect that Philco has sold its minority interest in Semiconductors, Ltd., Swindon, to Plessey. Semiconductors is now a wholly-owned Plessey subsidiary, and continues as a non-exclusive licencee of Philco with respect to the manufacture and sale of transistors.

THE S. S. WHITE DENTAL MANUFACTURING COMPANY (G.B.), Ltd., has opened a new works at Bletchley, Bucks, for the manufacture of industrial flexible shafting. This works, with a productive floor area of 51,000 square feet, is being equipped with plant for making the full range of flexible driving shafts in which the firm has specialised in this country since it was established in 1930 as a branch of the parent organisation in the United States.

E. K. COLE, Ltd., announces the formation of a new subsidiary company, Ekco Exports, Ltd. The new company will operate from the main Ekco works at Southend, and will handle the export of radio, television and car radio receivers, electric heating and plastics products produced by the Ekco Group. Mr. W. M. York is chairman of the new company, Mr. J. Corbishley, F.C.A., and Mr. D. J. Cole, B.A., LL.B., are directors, and Mr. T. C. Cleveland is director and general manager.

MULLARD EQUIPMENT, Ltd., is moving to its new factory at Crawley New Town, Sussex, on September 4. This new plant, of 134,000 square feet, will be staffed by about 600 employees who will move from other Mullard factories and by others recruited from the Crawley area. The site area of 17 acres leaves space for future extensions, and the present buildings are planned so that they can form part of a larger unit. The address of the company will be: Mullard Equipment, Ltd., Manor Royal, Crawley, Sussex, (telephone, Crawley 26386).

W. P. BUTTERFIELD (ENGINEERS), Ltd., has concluded an agreement with Ryan Industries, Inc., Cleveland, Ohio, U.S.A., whereby the British company will receive full technical information necessary for the manufacture of Ryan cryogenic equipment a its own works at Shipley. Cryogenic equipment—for the practical application of very low temperatures—will be made and sold by Butterfield to Ryan design in the United Kingdom. Under the agreement Butterfield also has the sole marketing rights for this equipment in the whole of Europe and West Africa.

MASSEY-FERGUSON, Ltd., Coventry, states that manufacture of Massey-Ferguson tractors in Brazil, as approved under the plans of Geimar, the Brazilian Government Agency, will shortly begin. This operation is being undertaken by Massey-Ferguson do Brazil, in association with the local firm of Vemag SA, distributors of M-F products since 1946. The factory, with a planned capacity for 400 tractors a month, is located in the industrial area of Jaquare, Sao Paulo. The tractors will be powered by Perkins diesel engines now being produced by Motores Perkins SA in Brazil.

FAG BEARING COMPANY, Ltd., announces that in common with its associated companies KUGELFISCHER GEORG SCHAFER AND CO., Schweinfurt, Western Germany; FISCHER BEARINGS MANUFACTURING, Ltd., Stratford, Ontario, Canada; and FAG BEARINGS (IRELAND), Ltd., Dublin, they are adopting a revised form of trademark. The letters FAG in modern form are now used without the familiar diamond outline. The company also announces the opening of a new depot at 92, Broughty Ferry Road, Dundee (telephone Dundee 83745) and the transfer of its north-eastern branch to 16, Dean Street, Newcastle upon Tyne, 1 (telephone Newcastle 24612).

Contracts

HEAD WRIGHTSON MACHINE COMPANY, Ltd., has received an order from the Steel Company of Wales for an Armco Sendzimir continuous hot dip galvanising plant, to be installed at Abbey Works, Port Talbot. The plant will be capable of galvanising cold reduced strip up to 54in wide and from 0·015in to 0·062in thick at a speed of up to 150ft per minute.

WAYNE KERR LABORATORIES, Ltd., has received its first order from abroad for a transfer function computer. It has been placed by Electricité de France, the French state electricity authority. E.D.F. is engaged in the analog computations of transmission line problems, and will use the Wayne Kerr S.A.100 in a method that involves setting up the transfer function of line networks.

CONSTRUCTORS JOHN BROWN, Ltd., has obtained a contract from Polimex, the Polish State trade organisation, for the design, supply and installation of three tonnage oxygen and nitrogen plants, to be used in the production of ammonia at Tarnow, in the south of Poland. The plants, worth nearly £2,000,000, will be completed successively within about five years, and will have a combined output of nearly 1000 tons a day of oxygen and more than 1100 tons of nitrogen. For ammonia synthesis the oxygen must be exceptionally pure, and must not contain more than 100 parts per million of other gases.

THE GENERAL ELECTRIC COMPANY, Ltd., has been awarded a 3,000,000 dollar contract by the Compania Nacional de Telefonos del Peru to supply the radio and multiplexing equipment for a microwave network linking the towns of Arequipa, Lima, Trujillo, Chiclayo and Piura in Peru. Comprising ten terminal and fifty-four both-way repeater equipments, the network will be the longest in South America, extending for 1100 miles along the Pacific seaboard. A main and a protection radio frequency channel operating in the 2000 Mc/s band will be provided on all routes. In the event of failure or degradation of the working radio channel, changeover to the protection channel is automatic. Each radio channel has a capacity of 240 speech channels. The equipment will be engineered and manufactured by the Transmission Division of the G.E.C. Telecommunications and Electronics Group, Telephone Works, Coventry.

E.M.I. ELECTRONICS, Ltd., has received contracts from the British Broadcasting Corporation for transmitting aerials and feeder systems at five new stations in Scotland, Wales, Cornwall, Lancashire and Oxfordshire, which the B.B.C. is building to extend its television and sound services and to improve reception in the fringe areas. At the v.h.f./T.V. station now under construction at Llandrindod Wells in Central Wales, super turnstile arrays have been installed on an 80ft section at the top of a 250ft mast. The stations under construction at Redruth, Cornwall and Beckley, near Oxford, will be equipped with television and v.h.f. sound arrays on 500ft masts later this year. Morecambe Bay station, to be built near Barrow, will be provided with a television aerial on a 250ft mast, while the Scottish station being built at Ashkirk, near Selkirk, will be equipped with television and v.h.f. sound arrays on its 700ft mast. All these arrays will be horizontally polarised with the exception of the television array at Ashkirk, which will be vertically polarised.

Miscellaneous

HEIGHT OF CHIMNEYS.—The Federation of British Industries has published a booklet containing the recommendations made by the Working Party appointed by its Air Pollution Panel to investigate questions concerning the height of new chimneys. The handbook entitled "Height and Design of New Chimneys" can be obtained from F.B.I. Print and Publications, 21, Tothill Street, London, S.W.1, price 4s., and refers to industrial boiler plants with an output of 5000 to 33,000 lb per hour of steam at maximum continuous rating.

Death

WE regret to announce the death of Mr. George H. Jackson, which occurred recently as the result of a motor accident. Mr. Jackson, who was seventy-two, was a pioneer of the mobile loading shovel, and was chairman of the Chaseside Engineering Company, which he founded soon after the end of the first world war. He produced his first Chaseside loader in 1925.

CONTINENTAL AFFAIRS

by Our Continental Editor

"Italia 1961" Exhibition at Turin

This year Italy is celebrating the centenary of her unification. The celebrations include the holding of a special exhibition at Turin, which is here briefly surveyed. Of interest to engineers is the large "Palazzo del Lavoro," designed by P. L. and A. Nervi, which was built for the present occasion but will be retained permanently. The roof which has a total area of 25,000 square metres consists of sixteen identical square sections, each individually supported by a central column.

THE celebration of the centenary of Italy's unification in 1861 is being marked by a National Exhibition in Turin, the city which played such an important part in the Risorgimento. Opened in May, the exhibition is continuing throughout the summer and early autumn until October. Its scope is threefold : historically, it presents a detailed survey of the events which led to independence ; developments since then, and the conditions in present-day Italy are illustrated in a Regional Exhibition ; while as a link with the world at large, the International Labour Exhibition depicts the principal changes which have occurred in the lives of the workers under the impact of scientific and technological developments and social reform.

The historical exhibition is housed in the Palazzo Carignano, in the centre of Turin, where on March 17, 1861, the Subalpine Parliament proclaimed the Kingdom of Italy. In this and other buildings—the Royal Library, the Royal Armoury, and the state archives—there are being shown historical exhibits documenting the event and the developments which led up to it.

Along the River Po, a large area has been prepared—much of it by building up the banks—for the Regional Exhibition and the International Labour Exhibition. The first of these is housed in nineteen riverside pavilions interlinked by elevated footpaths. These pavilions represent the regions of Italy, from Trentino-Alto Adige in the North to Calabria and Sicily in the south, and Sardinia in the west. Landscape, architecture, agriculture and industry, ancient and present-day culture, and the general mode of life of the people in the various parts of the country are the topics which are depicted here. Additionally, there is a "Unitary Pavilion" where some of the major aspects of the life of the country as a whole during the last hundred years are documented in an extensive pictorial display.

The Palazzo del Lavoro exhibition area which is nearly 1½km long is traversed by an "Alweg" monorail (Fig. 1) which may later be extended to the city centre. This monorail terminates at the "Palazzo del Lavoro" in which is being held the International Labour Exhibition. The building, which constitutes one of the main points of interest of the exhibition, is a 25m-high square structure with 158m-long sides and completely glazed external walls. It has been designed by Professor Pier Luigi Nervi and Antonio Nervi, in collaboration with the architect, Gio Ponti, who was responsible for the internal layout.

Fig. 1—A three-car monorail set for 340 passengers traverses the 1·2km long, 6m high elevated track at speeds up to 80 km.p.h. A magnetic device has been incorporated enabling the safety track at each end of the line to be reduced to approximately 50m

Fifteen countries and a number of international agencies have collaborated in this exhibition, each illustrating a particular facet of the general theme "Man at Work." Thus, Austria deals with "Work and Artistic Activities," Czechoslovakia with "The Co-operative Movement in Agriculture," Denmark with "The Housing Problem," Finland (in a very original display of photographs) with "Recreation," and so on. Much interest is being aroused by Britain's contribution, a show illustrating "Scientific Research."

The "Palazzo del Lavoro" (Fig. 2 and Table I) covers an area of 25,000 square metres on the ground ; the total available exhibition floor space, including an upper gallery, is 45,000 square metres, and the enclosed volume amounts to 65,000 cubic metres. For the construction very little time was available, the site being handed over only on January 1, 1960. Work began a month later, the structure being completed at the end of the year and the whole work on February 28 of this year.

TABLE—*Palazzo del Lavoro, Turin*

Length and width	158m by 158m
Height (overall)	25m
Covered area	25,000 square metres
Central floor space	22,500 square metres
Balcony	9000 square metres
Basement	6900 square metres
Volume	650,000 cubic metres
Height of main columns	20m
Number of main columns	Sixteen
Weight of each square roof section	125 tonnes
Roof area per section including lights	1600 square metres
Weight of steel roofing	20kg per square metre
Total steel roofing	2000 tonnes
Excavations, earth movements	120,000 cubic metres
Piled foundations, total length	12,000m
Concrete	16,500 cubic metres
Reinforcement steel	1500 tonnes

One of the aims of the design was to afford a maximum of flexibility for the internal arrangements. This was of importance not only in order to give the stand designers as much latitude as possible, but also in order to render the building useful on future occasions, for it is to be retained after the present exhibition is over.

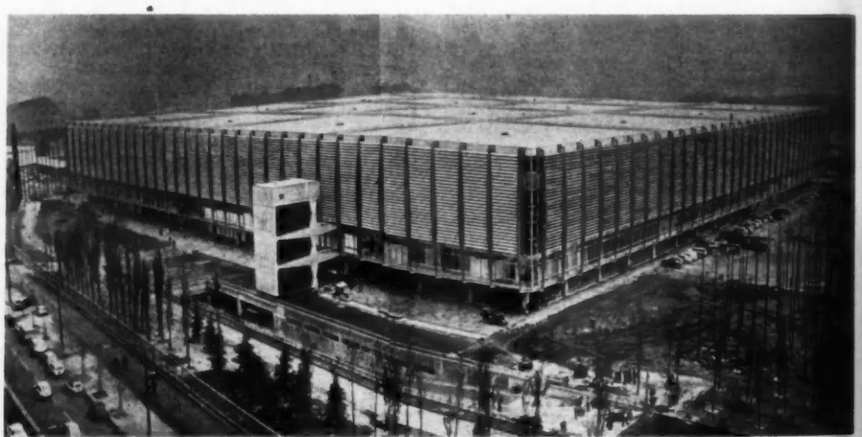


Fig. 2—"Palazzo del Lavoro" seen from the south. The illustration clearly shows the division of the roof into sections. The structure in the foreground adjoining the building houses a service lift

The solution adopted was to roof over the whole area by means of sixteen outsize "umbrellas," or "mushrooms," that is to say, square sections of roof measuring 39m along the sides, each individually supported on a tall column. The roof sections are completely independent, the 2m-wide spaces between them being spanned by glazed lights. Along the periphery runs an 18m-wide balcony supported on inner and outer columns spaced 10m apart, the balcony cantilevering by 4m on each side. On the inside the balcony is cut away at the corners, and in the vicinity of each of the columns, thus leaving room for the columns themselves as well as for staircases leading to and from the ground floor to the 5·5m higher upper level.

Fig. 3—Interior nearing completion. The steel roof sections, each supported on a 20m high concrete column, measure 38m by 38m, the 2m wide gap being bridged by glazed lights. Parts of the balcony and facade are also seen

Our illustration (Fig. 3) shows the interior at the time of construction.

Columns.—Spaced 40m apart, the reinforced concrete columns stand on cruciform slab foundations resting on *in situ* concrete piles. At ground level, the column section is also in the shape of a cross, measuring 5m between the ends of opposite arms, the arms themselves being 1m wide. At the top of the 20·85m high shaft the column section is circular, with a diameter of 2·5m. The visually very effective transition from one cross-section to the other is clearly seen in our illustration which also shows the pattern of straight lines left by the timber shuttering. The columns were carried up in six lifts, each double lift requiring twenty-four hours, after which the next section of shuttering and reinforcement rods was placed in position. Junctions between lifts were grooved for the sake of appearance. The cycle of construction for each column amounted to ten days.

The column shaft is surmounted by a concrete spigot 2·2m in diameter. This carries a steel hub 6m in diameter and not quite 4·5m high, from which radiate twenty cantilever steel beams which support the 38m by 38m flat roof. The roof fall is towards the centre, rainwater being drained through the column.

Besides the construction of the columns, another important problem was the concreting of the two reinforced concrete floors, the ground floor of about 7000 square metres, and the peripheral balcony of approximately 10,500 square metres. The time available for this task was rather short and the work had to be carefully co-ordinated with the erection of the metal roof. Casting of the ground floor had to precede the erection of the roof while the construction of the balcony, section by section, had to follow as closely as possible the completion of the corresponding parts of the roof.

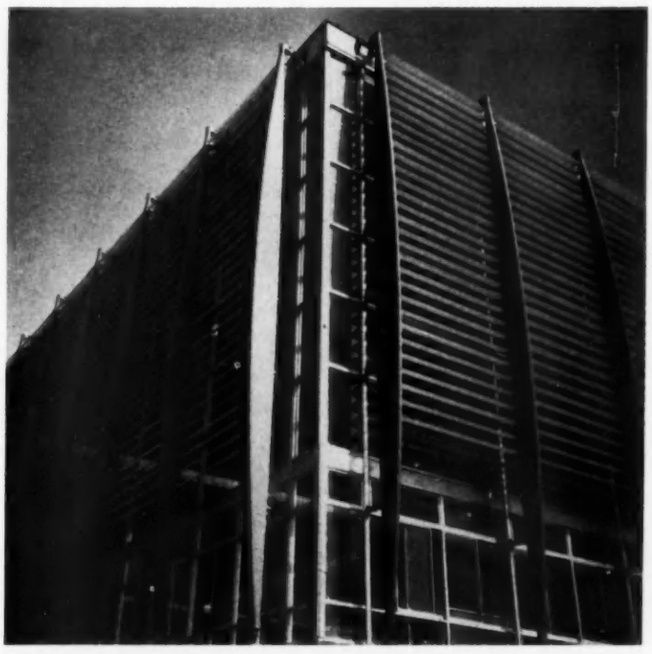
The main floor is designed for a load of 2 tonnes per square metre, and is built up of prefabricated slabs of 10m span supported every 1·66m on main beams cast *in situ*.

For the balcony, a design load of 400 kg per square metre was adopted. This floor was constructed with the help of concrete shuttering mounted on portable centring, which permitted rapid removal to the next position of a complete section of shuttering immediately after striking. The floor is based on a module of 5m by 10m. The concrete shuttering reproduced the complete shape of the underside including a complicated system of curved ribs, as shown in Fig. 4, no finishing operations being required.

For the preparation of concrete a mixing plant was set up approximately halfway along the southern frontage of the building, from where concrete was pumped to the various sections which were served by tower cranes operating on three tracks running north to south inside the building, in parallel with the lines of columns, and one external crane operating parallel to the the north frontage.

The four inner columns were constructed first, followed by the twelve outer ones, of which three were constructed in each case consecutively along the southern, western, eastern and northern frontages. Work on the balcony began on the southern side and proceeded in both directions around the perimeter to the opposite side.

Our illustration (Fig. 5) gives an impression of the method of glazing the façades. The frames are supported by bow-shaped vertical booms which are hinged at their upper ends to the edge of the roof and universally jointed to projections on the balcony at their lower ends. Louvres set between the spars shade the interior.



Figs. 4 and 5—(Left)—Underside of balcony, showing the system of curved ribs by which the centre span is reinforced. (Right)—The facades are fully glazed and supported against the wind pressure by vertical booms attached to the roof and to the balcony. Sun louvres shade the interior

CONTINENTAL AFFAIRS *(Continued)*

Silicon Rectifier Locomotives for the Congo

In the latest of the series of locomotives supplied from Belgium to the Bas Congo-Katanga Railway, two locomotives are equipped with silicon traction rectifiers and weigh 19 tonnes less than the corresponding design with ignitron rectifiers. The reduced axle-load is making it practicable to electrify secondary lines without relaying or strengthening the roadbed

NOT only was the Bas Congo-Katanga Railway in the Belgian Congo among the earliest post-war electrifications at industrial frequency, but it was the first to adopt the system commercially. Its 50-cycle contemporaries when the work was undertaken in 1950 were still at the stage of operating prototypes on routes chosen for their convenience as testing grounds rather than for traffic reasons. Four series of locomotives have been supplied to the railway since 1950 by the Ateliers de Constructions Electriques de Charleroi. They reflect the trend of industrial-frequency traction practice in the intervening years. All have the B_0-B_0 wheel arrangement; in the first batch each axle was driven by a double-armature a.c. series motor of 420 h.p., controlled by low-tension tap-changing. These locomotives were followed in 1956 by a further series, still with a.c. motors, but by now these were single-armature machines of 550 h.p., and nose-suspension had replaced the flexible drives used previously. Control was by high-tension tap-changer. In 1958, when ignitron rectifier locomotives were introduced, it was already planned that the last two units of this series should be equipped with silicon rectifiers. These two locomotives are now in service in the Congo. One of them is illustrated in Fig. 1.

The silicon rectifier locomotive has a continuous rating of 2000 h.p. at 28 m.p.h. and weighs 56 tonnes, as compared with the 75 tonnes of the corresponding design with ignitron rectifiers. On the a.c. side the power circuit comprises an auto-transformer with a Jeumont-Heidmann camshaft tap-changer through which a voltage variable in twenty steps is applied to a fixed-ratio main transformer. The secondary of this transformer is connected to two bridge circuits consisting of silicon cells in series-parallel, each bridge supplying two d.c. traction motors in parallel. There are seventy-two cells in each rectifier bridge.

In order to protect the cells against overloads the output current must be interrupted in less than a half-cycle. However, the motors are in series with smoothing chokes, and a discharge path has to be provided for this part of the circuit. As shown in Fig. 2, the input to the rectifiers is interrupted by opening the high-speed isolating switches *A* and *B* in the left-hand side of the bridge. Rectifiers 2 and 4 in the other two arms then form a discharge path for the motors and chokes. For this reason the silicon cells are not distributed equally between the arms of the bridge. Rectifiers 1 and 3 are each formed by four parallel circuits of four cells in series, but 2 and 4 each consist of five such circuits.

The contacts of switches *A* and *B* have a separation of only 1mm when open. They are arranged to open in the non-conducting half-cycle. For example, if the overload occurs when rectifiers 1 and 2 are conducting, *A* opens first, followed by *B* on the next half-cycle. This is followed by the opening of the normal motor circuit contactors. The moving contacts of the isolators are latched in the closed position against spring pressure, and are released in case of overload by the movement of an armature which is attracted by an electromagnet. Referring to Fig. 3, the magnet winding is energised by discharge of the capacitor, which takes place on the closing of a contactor energised from the fault-detection circuits. Normally a transistor blocks the passage of current through the contactor coil. On occurrence of a fault, a control impulse is generated by the electronic circuits 2 or 3 and, providing the rectifiers associated with this particular isolator are not conducting, is applied to the base of the transistor. This causes the transistor to conduct so that the contactor closes and the capacitor discharges through the magnet winding. Circuit 1, itself an arrangement of transistors, ensures that the impulse only reaches the transistor in a non-conducting half-cycle of the rectifiers concerned.

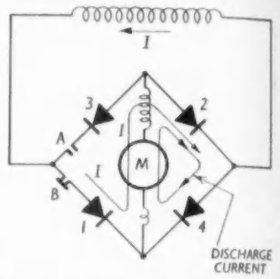


Fig. 2—Protection of rectifiers by high-speed isolating switches operating off-load

Circuits 2 and 3 respond respectively to overloads in the motor circuit and to failure of a rectifier cell. The motor overload protection system has no moving parts but operates on the transductor principle. One transductor winding carries a steady polarising current, while a second winding, in opposition to the first, carries the rectifier output current. If the latter exceeds a certain value a sharp reversal of flux takes place, so that a voltage is induced in a third winding. This is the signal voltage applied to the transistor as already described.

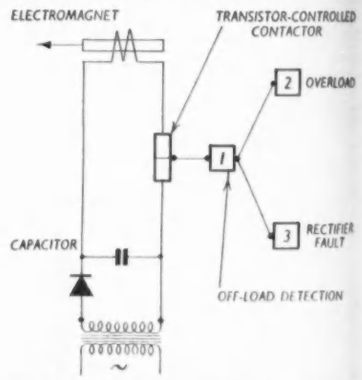


Fig. 3—Control of high-speed isolating switches

Faults in a rectifier cell are detected by transformers connected across points of normally equal potential in the rectifier network. Failure of a cell disturbs the balance and allows current to flow through the primary of one of the transformers, inducing in the secondary the signal voltage which is passed to the transistor of Fig. 3.

The protective system can be overridden by a voltage relay connected across the capacitor seen in Fig. 3. If the voltage across the capacitor

Fig. 1—2000 h.p. locomotive for the 25kV, 50 c/s system of the Bas Congo-Katanga Railway

is insufficient to energise the electromagnet, the relay is released and causes the motor contactors to open.

A cubicle measuring 1·65m high by 1m wide by 0·6m deep contains the complete assembly of rectifiers and protective devices for the four motors. The high-speed isolators and electronic circuits are on the top shelf. Below them are the rectifier cells, arranged with their cooling fins on the inside, projecting into a central cooling duct. The resistance and capacitor chains connected across the cells are in the next section, and at the bottom of the cubicle is the cooling fan. Since little heating of the air takes place, it is discharged inside the locomotive and passes to the traction motor and smoothing choke blowers.

The locomotive has rheostatic braking with a magnetic amplifier control system. A reference voltage set up by the driver's controller is compared with a signal derived from a tapping on the fixed braking resistor, the difference serving to control on a.c. voltage which is rectified and excites the motor fields. The excitation is thus adjusted automatically so that the current flowing in the braking resistors is held almost constant, for speeds between 15½ and 40 m.p.h.

Fig. 4—Driving controls and, on left, push-button panel for auxiliary services

The A.C.E.C. 472 traction motor used in these locomotives is a four-pole, nose-suspended machine rated continuously for a current of 460A at 880V. Cooling air flow is 100 cubic metres per minute. Weight without gears is 2100 kg. The bogie pivot height is as low as possible to reduce weight transfer, but in addition the fields of the motors driving the trailing axles in each bogie are automatically shunted to weaken them by about 6 per cent. Consequently these two motors take a slightly higher current and develop a greater effort at the trailing axles than the motors driving the more lightly loaded leading axles.

The layout of the driving cab (Fig. 4) is similar to that in the previous locomotives with ignitron rectifiers except that the push-button control panel for the auxiliaries is at right angles to the driving desk. The controller handwheel has ten positions, enabling ten operating characteristics to be selected. Progression to the notch selected is normally automatic, the rate of acceleration being controllable according to load by means of the handle at the top right-hand corner of the driving desk. During trials one of these 56-tonne locomotives has started a train of 1000 tonnes on the level without sanding or use of the field-shunting system mentioned above. With these two facilities in use, the same train was started against a gradient of 1 in 80, a tractive effort of 22·7 tonnes being developed. On the basis of these results, the Bas Congo-Katanga Railway is considering the electrification of lines where axle-load is limited to 15 tonnes without relaying or strengthening the track.

Nuclear Fusion Conference

An international conference on Plasma Physics and Controlled Nuclear Fusion Research will be held by the International Atomic Energy (I.A.E.A.) at Salzburg, Austria, from September 4 to 9, 1961. Of the approximately 250 papers accepted so far, about 100 will be presented orally. Some 500 scientists are expected to take part in the conference which, in addition to furthering nuclear research as a whole, is largely intended to help eliminate wasteful duplication of effort and expenditure in a field which requires nowadays extremely elaborate and costly facilities.

The Salzburg conference will also show what progress has been achieved since the Second U.N. International Conference on the Peaceful Uses of Atomic Energy, held in Geneva in 1958, where the previously classified results of fusion research were first made accessible to the scientific world at large.

The subjects to be discussed cover both theoretical and experimental aspects of plasma physics, ranging from general plasma theory and mathematics to problems of plasma confinement, stability, oscillation, heating and the interaction of plasma with particles.

Information Exchange on Energy with E.E.C. and Joint Steel Studies

At the eleventh meeting of the Council of Association between the United Kingdom Government and the High Authority of the European Coal and Steel Community on June 15, it was agreed that a special working party should periodically compare energy forecasts in the United Kingdom and the Community. Joint studies will also be made on how best to improve the efficiency of the coal industry through the application of modern scientific methods to mechanisation. The Coal Committee's Working Party on Long-Term Trade Prospects is to continue to examine ways of developing mutual trade in solid fuels between the United Kingdom and the Community.

The Council was given an account of the improvement in the coal situation both in the United Kingdom and in the Community. In the United Kingdom coal consumption rose by nearly 7·5 million tons between 1959 and 1960. Undistributed stocks fell by more than 6,000,000 tons in 1960 and a further fall of 8,000,000 tons is expected this year.

In the Community inland demand for coal was nearly 8,000,000 tons greater in 1960 than in 1959, and exceeded production by 18,000,000 tons. Stocks were reduced by 3·5 million tons and are expected to fall further in 1961.

The Council was informed that, as a result of vigorous sales promotion, good progress had been made both in the United Kingdom and the Community in bringing home to the public the advantages of coal as an efficient and modern alternative to oil.

The year 1960 was a record one for steel both in the United Kingdom and in the Community. In the United Kingdom production rose from 20·5 million tons in 1959 to 24·3 million tons in 1960, and in the Community from 63·2 million tons to 72·8 million tons. Studies by the Iron and Steel Board and the High Authority indicate that by 1965 the demand for steel will reach 29,000,000 tons (including exports) in the United Kingdom, and between 87,000,000 and 98,000,000 tons in the Community, depending on the level of industrial activity.

The Council authorised its Steel Committee to engage in studies of the raw materials consumed in steelmaking in the United Kingdom and in the Community, and of the application of automation to the iron and steel industry.

Seventy-Five Years of Oil Tanker Operation

Seventy-five years ago, on July 10, 1886, the first ocean-going steam-powered tanker was put into service. This was the "Glückauf," 3000 tons dwt., built by W. G. Armstrong, Mitchell and Co. at Low-Walker-on-Tyne. She had an overall length of 97m, a beam of 11·4m and a draught of 5·8m. Powered by a 1000 h.p. triple expansion steam engine, the vessel achieved a speed of 10·2 knots. Her owner was Wilhelm Anton Riedemann, of Geestemünde, who four years later, together with other German petroleum importers and the Standard Oil Company founded the German–American Petroleum Company Ltd., the present-day Esso A.G. It was his idea to build a ship with engine aft and a compartmented hull which would form the oil tank. Already in 1885 Riedemann had had his sailing ship "Andromeda" equipped with fixed oil tanks and in this way had increased her capacity from 12,000 to 17,000 barrels (approximately 2700 tons dwt.).

At the present time the world tanker fleet comprises some 3000 units of over 6000 tons dwt., totalling approximately 65,000,000 tons dwt. Of these, 58 per cent belong to independent shipowners, 33 per cent to oil companies, and 9 per cent are state-owned.

Esso A.G.

During the year 1960, Esso A.G., Hamburg, increased its turnover by DM.208·5 million to DM.2429·4 million. Intensive efforts to rationalise the company's operations are mentioned as one of the chief factors which permitted the making of a moderate profit of DM.47·8 million gross (DM.1·7 million net). At the recent annual general meeting a further increase of the share capital by DM.100 million to DM.450 million was approved, following last year's increase of DM.50,000,000. Project studies were continued for the Upper Rhine Refinery near Karlsruhe which is to have an annual throughput capacity of 3·6 million tonnes. Construction is to start in the course of the summer and the refinery is to come on stream early in 1963. A further refinery is to be completed in the region of Ingoldstadt in 1964.

The two existing Esso refineries have increased their throughput to 5·9 (5·1) million tonnes. Imports amounted to 6·1 (5·5) million tonnes of crude and 1·7 (0·8) million tonnes of refined products. Additional plant at the Cologne refinery is to come into service this autumn. This will double the output of ethylene and butadene; in addition the manufacture of high-purity tetra propylene as well as methane and hydrogen will be taken up. Investments included DM.5,000,000 for the new research laboratory in Hamburg as well as DM.8,000,000 for various research and development projects.

Fabrication of Frictional Parts in Europe

It has been announced by the American Metal Products Company of Detroit, Michigan, U.S.A., that the "dry" or greaseless bearings that it manufactures with "Fibreglide"* are now to be manufactured under licence in both the Common Market and Free Trade areas, respectively by Lemforder Metallwarengesellschaft m.b.H. and by Engineering Productions (Clevedon), Ltd., in England.

These bearings were described and a ball joint for automotive steering and suspension movement illustrated on July 6, 1956, page 32; the originating firm expects that these bearings, which not only dispense with maintenance but also improve the performance of, for instance, automobile suspensions, will be adopted by United States motor manufacturers. There are also available bearing elements, such as bushes or thrust washers, for incorporation in mechanisms.

[Reply Card No. 1149]

* Du Pont "Teflon" polytetrafluoroethylene in its fibrous high load-carrying form.

THE AMERICAN SCENE

By Our American Editor

Automatic Continuous Copper Rod Mill in New Jersey

A HIGHLY automatic, continuous "Loewy" copper wire rod mill recently went into production at the Linden works, in New Jersey, of the Hatfield Wire and Cable Division of Continental Copper and Steel Industries, and is turning out high-quality $\frac{1}{4}$in copper rod from 4in by 4in wire bars at rolling rates as high as 17 tons per hour. Demonstrating the economic feasibility of continuous mills for smaller works, the new installation was designed and built by the Baldwin-Lima-Hamilton Corporation, Industrial Equipment Division, of Eddystone, Pennsylvania. Designed for economical one-shift-per-day operation at output speeds up to 2700ft per minute, the continuous mill provides greater productivity than conventional rod mills designed with looping or Belgian stands. Looping stand mills generally cannot operate more rapidly than at about 1200ft per minute, representing the maximum speed at which tong men or catchers can grasp the hot, fast-moving rod and loop it between mill stands. The use of the continuous mills at Hatfield has also reduced floor space requirements considerably over those of equivalent conventional mills. The mill and its furnace occupy an area only 70ft by 220ft.

Three men can operate the mill—one stationed at the furnace, one at the pulpit, and one at the coil unloader: conventional installations of the older type required between twelve and twenty-five men. The mill reduces a standard size 250 lb to 265 lb copper wire bar to $\frac{1}{4}$in copper rod in fourteen passes in eighty seconds. The mill is designed to handle either continuously cast copper bars or conventionally cast 300 lb wire bars. Because the larger bars yield larger coils, fewer welds are needed to join the coil ends at subsequent drawing operations. The mill can handle continuously cast billets without the need for machining the square ends of the billets to a taper. Conventional mills with a small roughing stand require this costly operation to enable the roughing mill to grasp the material. The higher finishing speeds used also reduce scaling and result in less loss of copper in the pickling tanks.

The new installation (illustrated) consists of a completely mechanised 24in hot breakdown mill, three 12in intermediate continuous mill stands, six 10in finishing stands, a walking-beam entry furnace, and pickling, coiling, and storage facilities. The new mill represents a further step in Hatfield's "vertical" integration. The firm can now conduct all operations from producing wire rod from wire bar on to the finishing of insulated wire and cable. Moreover, should future needs dictate the step, facilities for the continuous casting of copper billets from virgin copper and selected scrap can be added to provide a further integration.

A walking-beam gas-fired furnace built by the Surface Combustion Company is used to heat the wire bars to rolling temperature. A furnace of this design was deemed superior to the conventionally used pusher furnace because the walking beam is better suited to automatic operation and co-ordination with the mill. The walking beam design also eliminates scoring of bars and permits the furnace to be emptied easily at the end of a shift. The compact furnace has small side entry and discharge ports, to obtain better atmosphere control and good thermal efficiency. The bars are heated in about fifty minutes.

The 24in diameter three-high roughing mill is capable of biting large sections and needs no roughing of rolls to get a grip on the bars. This feature ensures improved quality and an easy entry in automatic operation. In the roughing mill, the pass layout design is such that four rolls are equivalent to two sets of rolls, as against the usual six rolls to two sets. Automatic manipulating tables turn the bar through 90 deg. for each of the five roughing passes made, rather than the more conventional turn for every other pass. This arrangement provides better mechanical working of the metal. To reduce wear and the frequency of roll change, the roughing rolls provide a minimum of two sets of grooves for each pass. The change-over from one set of roughing passes to another takes about fifteen minutes. A roughing mill stand shifting device shifts the entire stand so that the tables are in line with new grooves on the roll.

At the end of the roughing passes, the standard, trapezoidal bar of approximately 4in by 4in has been reduced to an oval approximately $2\frac{1}{4}$in by $\frac{13}{16}$in in size. An interesting design aspect is the use of an a.c. squirrel-cage drive motor designed to give a simplified design and eliminate the flywheel, large bearings, and attendant maintenance.

The finishing passes are taken in two-high continuous mill stands, each stand taking one pass. Switching and guiding equipment for the continuous finishing mill stands is provided for running on a minimum of two tracks, even though the rated production of the mill requires only single stranding. Thus, single stranding

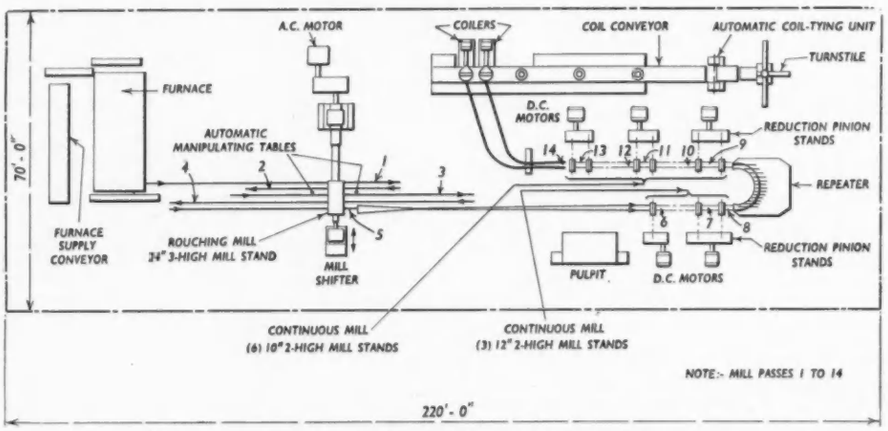


Fig. 1—Layout of Loewy continuous copper wire rod mill in New Jersey

Fig. 2—Loewy continuous copper wire rod mill, with coil conveyor and automatic tying unit in foreground

can be carried to its limit without interference between the front and back ends of the bar. Roller bearings are used on all mill stands to decrease power consumption and to permit using smaller drive motors.

A repeater stand automatically brings the wire around between the 12in intermediate and the 10in finishing stands. This arrangement permits flexibility and facilitates adjusting the speeds of the individual eleven motors in the train. The repeater is behind the third intermediate stand, where the wire is square in cross section and of a size adequate to provide the reliability of looping required in an automatic mill. To minimise copper pick-up and scratching on the guides and strippers, considerable attention was given to these elements. Being made of a special, super-hard material, the critical guides and strippers have low friction and can resist pick-up. Consequently, the mill downtime, usually needed to maintain the guides, is substantially reduced. Similar hard materials are also used on the guide equipment used to control the ovals between mill stands.

Automatic Garrett-type coilers, with low inertia to obtain minimum recovery time, coil the finished wire. A conveyor carries the coils through a water quenching tank. After the coils are tied by an automatic coil tying machine, which makes two ties 180 deg. apart, they are removed by forklift truck from a turnstile and carried to the batch pickling system.

High-Energy-Rate Compacting

FOR the past several months, the American Brake Shoe Company has been conducting metal forming experiments at its Research Centre in New Jersey, using an exceptionally large vertical "Dynapak" metal forming machine, developed by the General Dynamics Corporation. The machine, illustrated in Fig. 1, has a maximum energy of 431,000 lb feet and a cycle time of 105 seconds. Its ram velocity ranges from 250in to 1500in per second, its stroke is 15in, its firing pressure is 2000 lb per square inch, and it has a dwell time of one second. It can accommodate die sizes up to 22·5in in diameter.

The "Dynapak" unit is an unusual high-energy-rate metal forming machine. Its special properties are derived from the high speeds at which it operates, and at maximum velocity, it is about 100 times faster than the fastest "high-speed" extrusion press of conventional design. Utilising its tremendous pneumatic power, the machine can perform such metal-working tasks as forging, extruding, compacting and blanking. In addition to forming carbon and stainless steels, copper and aluminium, the unit is capable of processing metals that up to now have been difficult or impossible to work. Such "exotic" metals as tungsten, molybdenum, titanium, columbium and zirconium have been successfully shaped into intricate parts by the equipment. Although the American Brake Shoe Company is primarily interested in forging and compacting applications, it has constructed a pit below the "Dynapak," which will permit limited extrusion work as well.

The "Dynapak" operation is based on the principle, of pneumatics. In one chamber, compressed nitrogen gas is stored under high pressures up to 2000 lb per square inch. When the unit is in a "cocked" position, low pressure gas at 200 lb per square inch in a second chamber holds the working piston against an orifice plate. A seal in the piston face isolates all of the piston surface from the high-pressure gas, except the small area surrounded by the seal. With the high-pressure gas acting on the small area and the low-pressure gas pushing against the larger area, a balanced condition is achieved. When the "Dynapak" is triggered, this balanced condition is upset by a slight additional pressure on the high-pressure side of the piston. As the piston starts to move, the seal is disengaged, exposing the entire face of the piston to the high-pressure gas. Greatly overbalancing the low-pressure gas in the other chamber, the released high-pressure gas fires the piston at velocities up to 2000in per second. The speed is dependent upon the size of the piston, the pressures employed in the two chambers, and the weight of the ram.

As shown in Fig. 2, one die or punch is mounted on a ram attached to the moving piston. The other die is placed in the bolster. After the machine is fired, it is re-cocked by a hydraulic pump which re-compresses the nitrogen in the high pressure chamber. The entire working cycle—cock, release, re-cock—is completed every 105 seconds.

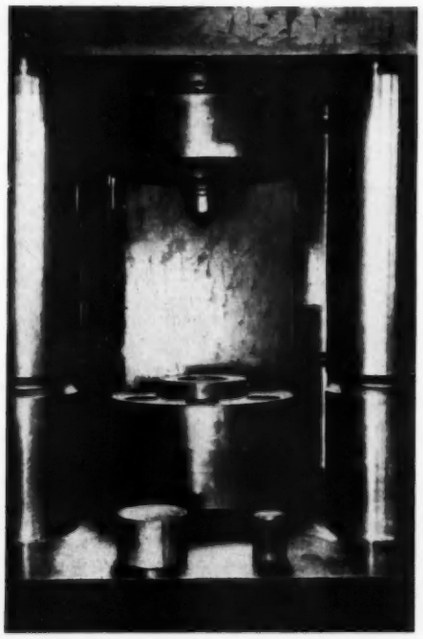


Fig. 2—Close-up view of the "Dynapak" tooling used to form a steel piston cap

To dissipate such tremendous energy, conventional machines require a large foundation. However, the "Dynapak" is designed with a self-reacting system which works on a principle similar to that used in artillery recoil. When the piston is released, the heavier cylinder and tie rods move slowly in the opposite direction. Hence, the momentum of the frame reacts against the momentum of the piston. Because of this self-reaction, there is almost no impact loading on the flooring, and the machine is held in place only by a few bolts embedded in concrete.

So far, the firm has employed the equipment to form intricate parts from aircraft quality S.A.E. 4130 steel, tough pitch copper and copper powder compacts. In 4130 steel, a cone-shaped piston-cap for a hydraulic landing gear strut was formed from a 2in diameter by 2in long cylindrical billet. The billet was first heated to 2150 deg. Fah. in a salt bath furnace adjacent to the "Dynapak" machine. Both die sections are lubricated with a graphite and water solution to reduce the possibility of the hot-forged part sticking to the punch or in the die. This part is formed with a wall thickness of 0·180in, a variation of ±0·005in, and a concentricity value of ±0·010in. The surface finish is superior to the finish achieved

Fig. 1—Large vertical "Dynapak" metal-forming machine installed at the American Brake Shoe Company

THE AMERICAN SCENE *(Continued)*

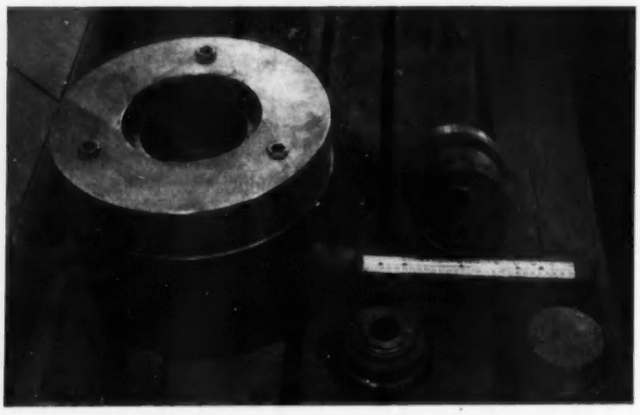


Fig. 3—Close-up view of the punch and die used to form a copper oxygen nozzle, shown in foreground

by normal forging methods. On this part, there is practically no scrap loss. A very small amount of flash is forced into a thin ring at the outside edge of the cap where it can easily be turned off by machining. On conventional press forging equipment, this same part would require at least four press strokes and finishing on a cold trimming press. Then it would still need inside and outside machining, to conform to the customer specifications.

In another experiment, it was desired to establish the feasibility of forming powdered compactions. The firm utilised the tooling for the steel piston cap to form a cap from a powder copper compact. The powder compact enabled it to add certain properties to the cap which would impart increased strength and resistance to abrasion and erosion at high temperatures. These characteristics could not be introduced to molten metals. The weight of the powder copper billet was 2·10 lb, and its density was 65 per cent. After being sprayed with a water-soluble lubricant, the billet was heated to 1450 deg. Fah. in a gas-fired furnace. A light coating of graphite was used to lubricate the tooling. The experiment was successful. The copper cap was formed in one stroke with almost no metal loss. The density was 98 per cent minimum. A small amount of flash was contained in a thin ring around the outside edge of the cap, as it was on the steel part. The surface finish and grain flow were excellent.

The tough pitch copper part shown in Fig. 3 is a nozzle for a steel mill oxygen lance, which is normally machined from solid bar stock. The copper billet weight is 9·10 lb, and after a blow by the "Dynapak," the finished nozzle weighs 8·90 lb. It has a ¼in diameter hole and is 2½in deep. The combined results of these two experiments indicate that a copper oxygen nozzle with new improved qualities can be produced on the "Dynapak" by a powder metallurgy technique.

The "Dynapak" method has proved most effective where high-cost metals must be formed in intricate shapes to extremely close tolerances. When forging such precision parts, low velocity presses and hammers often leave much to be desired; they push metal into die cavities at relatively slow speeds, and the limited metal flow often results in wide tolerance ranges and imperfect surface finishes. On the other hand, the high ram velocity of the "Dynapak" creates tremendous abrupt pressures within the die cavity. These high pressures cause severe deformations, and the metal moves faster and farther than when formed by conventional methods. Even tough, hard or brittle materials exhibit a plastic behaviour when hit, and flow smoothly and evenly into every die opening. Thus, compared with normal forging techniques, "Dynapak" is capable of forming parts with thinner sections, superior grain flow and greater strength, finer surface finishes and closer dimensional tolerances. In addition, on certain alloys with narrow forging temperature ranges, it can increase the rate of production. One "Dynapak" stroke can produce a part that would normally require several press or hammer strokes with reheats in between the strokes. With the new machine, the punch remains in the die for such a short time that there is little opportunity for overheating. Pressure is applied and released so quickly that metal is completely formed before the die has a chance to deform beyond its elastic limit.

In European markets, the above development is being handled by Brakeshoe International, S.A., of Geneva, and by Lloyds-Brakeshoe, Ltd., of Burton-on-Trent.

Lower Cost of T.V.A. Power

The board of directors of the Tennessee Valley Authority has announced the availability of a new and lower electric power rate for residential, farm, and commercial users. The new rate has been designated as the Norris Centennial rate in honour of the late Senator George W. Norris, on the one-hundredth anniversary of his birth, and provides the lowest rates anywhere in the United States for the amount of electricity used in the average home. Senator Norris led a long and successful fight for Tennessee Valley resource development and for lower electric rates everywhere in the country.

The new rate schedule may be placed in effect at the option of any of the 155 locally owned distribution systems which serve the 1,500,000 customers in the 80,000 square mile area served by T.V.A. power. Two of these retail distributors have already announced the adoption of the new rates. The T.V.A. power system is primarily a wholesaler of electricity. It generates and transmits power to the local systems, of which 102 are municipally owned, fifty-one are rural electric co-operatives, and two are private companies. These local enterprises sell the electricity to their customers at rates agreed upon in contracts with T.V.A. Such agreements until now have allowed for three different rate levels. The new action makes a fourth schedule of rates, the lowest of all, available.

The Norris Centennial rate will affect most significantly customers who use more than 250kWh of electricity a month. For example, a home or farm using 500kWh a month would pay 4·50 dollars a month or 54 dollars a year as compared with 6·90 dollars a month or 82·80 dollars a year under the highest rate in the T.V.A. service area. For commercial users the new rate would mean a reduction of about 8 per cent from the present lowest level. It will affect mainly the smaller commercial establishments, such as shops and small office buildings.

Largely as a result of low rates, the residential consumers in the T.V.A. area have been increasing their use of electricity at the rate of about 11 per cent a year. Homes and farms in the T.V.A. service area use more than 9000kWh (each) yearly, on an average, compared with the national average of 3900kWh. The average cost of T.V.A. electricity to residential and farm consumers is 0·98 cents per kilowatt-hour, as against the national American average of 2½ cents.

Operational Testing of Nuclear Ship "Savannah"

The U.S. Atomic Energy Commission has authorised, subject to certain conditions, the fuelling, start-up and operation of the reactor of the N. S. "Savannah," the world's first nuclear cargo-passenger ship, for test and demonstration purposes at Camden, New Jersey, and Yorktown, Virginia, and for the initial sea trials of the vessel.

The construction of the "Savannah" was authorised by Congress in 1956, as a joint project of the U.S. Atomic Energy Commission and the Maritime Administration of the U.S. Department of Commerce. The primary purpose in building the "Savannah" has been to produce a prototype vessel which would serve as a forerunner of other commercial nuclear vessels and as a test plant to permit the development of improved components and techniques for nuclear ship operation. Under a memorandum of understanding between the A.E.C. and the Maritime Administration, the Commission was assigned the development of the nuclear power plant and the Maritime Administration was assigned the design and construction of the ship and its operation. The memorandum established a Maritime Administration-Atomic Energy Commission Joint Group to carry out tasks related to design, development, testing and operation of the ship. The vessel is now at the yards of its builder, the New York Shipbuilding Corporation, Camden, New Jersey.

Although the "Savannah" will not be subject until later to the Commission's licencing requirements, the Commission has applied the same standards to the review of the nuclear safety aspects of the vessel's construction and operation as are applied in the review of licenced reactors. The action of the Commission covers five phases of testing and initial operation of the "Savannah." These are tests to determine the adequacy of construction and installation of machinery, components, wiring and piping (Phase I); a "dummy run" in which all reactor systems were operated concurrently without the use of nuclear fuel (Phase II); loading of fuel elements and concurrent testing at the shipyard of the New York Shipbuilding Corporation (Phase III); progression from zero power to operation at not more than 10 per cent full power at the Camden location and, after transfer of the ship with the reactor shut down from Camden to a site on the York River near Yorktown, Virginia, completion of dock trials up to full power (Phase IV); and sea trials off Virginia by the builder with Yorktown as an operating base (Phase V). The Commission's review did not cover Phase VI, consisting of extended sea trials, to be conducted by the States Marine Lines, of New York, as general agent of the Maritime Administration.

The "Savannah" was named for the S.S. "Savannah," first steamship to cross the Atlantic Ocean, and is equipped with a pressurised water reactor manufactured by Babcock and Wilcox. Its uranium oxide fuel, enriched to 4·4 per cent in uranium-235, is expected to provide power to operate the ship for 3½ years, or 300,000 nautical miles, without replacement. The reactor has a power rating of approximately 70 thermal MW. After the completion of the test programme at Camden at 10 per cent of its reactor power, the "Savannah" will move to Yorktown under steam supplied by temporary oil-fired boilers located in a cargo hold of the ship.

The "Savannah" is a sheltered deck vessel with a modified U.S. Mariner hull. The ship is capable of carrying 60 passengers, a crew of approximately 110 and about 10,000 tons of dry cargo at a sustained sea speed of 20·25 knots. The vessel was designed by George G. Sharp, Incorporated, of New York. The keel of the "Savannah" was laid on May 22, 1958, and the vessel was launched on July 21, 1959.

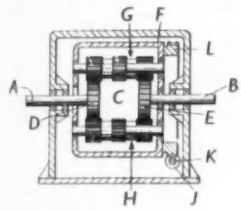
BRITISH PATENT SPECIFICATIONS

The dates printed are those of application and publication on completion. Copies of specifications may be obtained at the Patent Office Sales Branch, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each

ELECTRICAL ENGINEERING

873,701. July 29, 1958.—TESTING DYNAMO-ELECTRIC MACHINES, The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2. (*Inventor : Albert Bernard Cape.*)

An object of the present invention is the provision of means whereby full load testing of large induction and synchronous motors may be carried out at relatively low cost and during normal working hours with but a small demand on the local electric power supply. Referring to the drawing, the application of the invention is to the testing of large three phase a.c. induction motors of several thousand horsepower and the differential gear is of a size adapted for the translation of the necessary amount of power. Two similar motors, not shown, have their rotors coupled one to each of the output shafts *A* and *B* of a differential gear indicated generally by the reference letter *C* which is of the epicyclic kind having a first sunwheel *D* and a second sunwheel *E* disposed within an annular carriage *F*. To provide a differential action between the two sunwheels they are connected together with two pairs of layshafts *G* and *H*. The arrangement of the gearing (described in detail in the specification) is such that if sunwheel *D*, for example, is rotated in one direction and the annular carriage *F* is held stationary, then sunwheel *E* will rotate in the other



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direction at the same speed. A worm drive mechanism for rotating the annular carriage comprises a worm *J* having a driving shaft *K* and a wheel *L* attached to the annular carriage. The stators of the motors are connected to a three phase supply so that the shafts *A* and *B* rotate in opposite directions. The worm shaft *K* is coupled to a prime mover, not shown, such as an electric motor of relatively low horsepower. In operation if the electric power supply to the induction motor stators is switched on, the rotors will rotate at the same speed on no load and the worm shaft *K* will be stationary. Any losses in the differential gear will be supplied by the electric supply. If the worm shaft *K* is rotated in one sense, it will have a braking effect on one induction motor and cause it to transmit a torque to the other motor. This torque combined with the rotation of the worm shaft increases the speed of the driven motor, which generates power which is fed back into the electric power supply. If the sense of rotation of the worm shaft is reversed, then the roles of the two motors are reversed. By rotating the worm shaft at a selected speed, each of the induction motors can be tested at full load and this without any large power demand on the power supply, which merely deals with iron, windage and friction losses and the worm shaft supplies the combined slip energy of the induction motors. In testing synchronous machines, for example synchronous motors, the same apparatus would be used and one would act as a driving motor and the other as a driven machine. By angular adjustment of the annular carriage *F*, the phase of the driving machine can be adjusted to be in synchronism with the power supply. After effecting synchronism, further adjustment of the worm shaft to produce relative displacement of the rotors of the two machines enables the machines to deliver up to full output either motoring or generating.—*July* 26, 1961.

FOUNDRY EQUIPMENT

872,643. August 14, 1958.—PRODUCING MOULDS FOR FOUNDRY PURPOSES, Sulzer Frères, Société Anonyme, Winterthur, Switzerland.

This invention relates to a method of producing moulds with patterns which are removed by melting, burning, or dissolving out. As a rule, such patterns are formed from a wax or a thermoplastic material but urea as a pattern material is distinguished by a number of advantages. Its price is much lower than that of pattern wax, moreover, urea in the solid state has a very good rigidity even at elevated temperatures. Further, urea melts at 132 deg. Cent. which enables the pattern to be formed in conventional injection machines, using low working pressures. In addition to these properties, urea is water-soluble, and it is possible to remove the patterns from the mould with the aid of cheap aqueous solvent, in comparison with trichloroethylene used as already proposed for dissolving out wax patterns. According to the invention, use can advantageously be made of a pattern formed from molten urea and polyvinyl alcohol. The polyvinyl alcohol to be mixed with the urea may have a degree of polymerisation of from 200 to 300. Instead of polyvinyl alcohol, the substance increasing the toughness of the finished model may comprise a water-soluble urea-formaldehyde condensation product or partially polymerised water-soluble maleic acid.—*July* 12, 1961.

CONVEYORS AND ELEVATORS

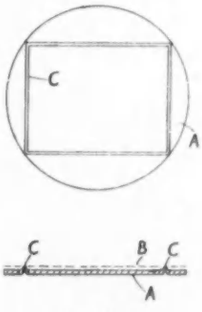
873,306. November 4, 1957.—TENSIONING MECHANISM FOR ENDLESS CONVEYOR BANDS, Keelavite Company, Ltd., Allesley, Coventry, Warwicks. (*Inventor : Eric William Reid.*)

This invention relates to tensioning mechanism for endless conveyor bands and is particularly but not exclusively applicable to the wire webs used in paper-making machinery. The tensioning mechanism includes a jockey roller biassed on to the band at one point and an adjustable roller bearing on the band at another point in its length. Operating mechanism is provided for moving the adjustable roller to control the tension of the band and control means are operated by movement of the jockey roller out of a predetermined position so that when movement of the jockey roller occurs the adjustable roller is automatically moved to adjust the band to restore the jockey roller to its predetermined position, and thereby maintain constant tension in the band. In a convenient arrangement the adjusting mechanism may be hydraulically operated, and the adjustable roller operated by a reversible hydraulic motor, the supply of operating fluid to the motor being under the control of a control valve operated by the jockey roller. Details and drawings of the mechanism and controls are given in the specification.—*July* 19, 1961.

TELECOMMUNICATIONS

873,041. August 27, 1959.—TELEVISION CAMERA TUBES, English Electric Valve Company, Ltd., Queens House, Kingsway, London, W.C.2. (*Inventor : Eric Douglas Hendry.*)

One of the difficulties met with in image orthicon and similar television camera tubes is that the membrane forming part of the target structure is very apt to vibrate at its own natural frequency and/or at a frequency harmonically related thereto if the tube is subjected to mechanical shock or vibration or even strong acoustic waves. If such acoustically or mechanically induced vibrations occur there are corresponding vibrations in the storage capacitance and interference signals appear in the output signals from the tube. The invention



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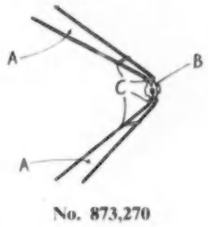
seeks to provide improved signal storing target structures for image orthicon and similar camera tubes. Referring to the accompanying diagrams of one form of the invention, the signal storing target structure consists of a very thin glass membrane *A* and a spaced mesh *B*. The useful picture area of the structure is the area within the rectangle which appears in the upper drawing. In order to prevent diaphragm-like vibration of the glass membrane and consequently microphony, a rectangular stiffening web is formed in the membrane. This stiffening web, *C* is in fact the rectangular frame which surrounds the useful picture area. It is formed merely by moulding a ridge in the glass membrane during manufacture to constitute the rectangular web. The height of the ridge is chosen to accord with the required spacing between the mesh *B* and the part of the membrane inside the web, i.e. the useful picture area. To quote a practical figure, this height might be 0·002in. In a modification, instead of forming the rectangular frame as a ridge moulded in the membrane, it may be constituted by a separate rectangular frame made of glass matched to that of the membrane and having the required thickness. This separate frame of glass is of the same shape and size as the ridge and is simply placed in position on the glass membrane and sealed thereto. In a modification the glass membrane is dished so as to consist of an outer and an inner portion which lie in parallel planes, the central portion of the membrane being a short distance—say 0·002in—below the outer portion and being joined thereto by the substantially vertical walls provided by dishing. The inner portion is rectangular and corresponds with the useful picture area.—*July* 19, 1961.

873,270. August 26, 1958.—AERIALS, Labgear Ltd., Willow Place, Cambridge. (*Inventor : John Roy Killeen.*)

The present invention aims to provide an aerial which can receive signals over a wide range of frequencies, for example, the various frequency bands employed for television and v.h.f. sound broadcasting, and is highly directional at the higher frequencies of operation in order to enhance signal pick up and eliminate the reception of multiple images. In the embodiment illustrated the aerial consists of two electrically conducting members generally indicated at *A* which are inclined to each other by an included angle of substantially 90 deg. and supported at their inner ends by an insulator *B*. Each electrically conducting member consists of two elements which are arranged fanwise in the same plane and connected together by shorting clamps *C*. The aerial is intended to receive television signals in the frequency ranges known as band I and band III as well as v.h.f. sound signals on frequencies within band II, and must, therefore, receive signals within the frequency range of approximately 40 to 220 megacycles. To this end, each conducting member is given a length of approximately 6ft 2in and the space between the open ends of the two elements forming each member is of the order of 13in. The aerial also has a characteristic impedance between the free ends of the members



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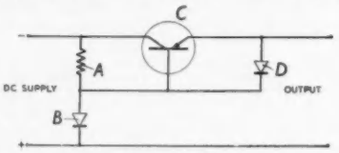
which is approximately equal to that of free space, that is of the order of 376·7 ohms, when the aerial is operating on signals within band III, when it functions as a terminated travelling wave aerial and its polar response is substantially unidirectional. In theory, this enhances the aerial gain by an additional factor of 3 dB and in practice such a figure is almost obtained. The ratio of the length of each conducting member to the diameter should preferably be approximately 20 : 1 to produce the desired characteristic impedance but since in practice it is inconvenient to provide such thick members, which in the present embodiment would be of the order of 3½in in diameter, the alternative construction illustrated is employed in which each conducting member consists of two elements arranged fanwise. This arrangement enables the aerial element to be constructed from metal tubing of the order of ½in diameter, such as is commonly employed for the manufacture of television receiving aerials. The fanwise arrangement of the elements also enhances the bandwidth of the aerial. The broad bandwidth produced

by the fanwise arrangement of the elements enables the aerial effectively to receive television signals on all the five channels of band I with approximately the same efficiency as a half wave dipole. The aerial is substantially omni-directional on band I and if unidirectional results are required, a reflector must be added. Examples are shown in the specification.—*July* 19, 1961.

ELECTRONICS

873,758. May 12, 1958.—PROTECTING CIRCUIT ELEMENTS IN ELECTRONIC CIRCUITS, The Plessey Company, Ltd., 1, Broad Street Place, London, E.C.2. (*Inventor : Leonard Charles Walters.*)

This invention relates to arrangements for protecting electronic circuit elements against damage by overloading. It is applicable to a wide variety of circuits, but is perhaps of especial interest in connection with certain circuits employing transistors. A circuit in which the invention is of especial interest is one in which a transistor is employed as an emitter-follower with the base electrode held at a constant or nearly constant potential by means of a reference voltage or current source with or without an associated amplifier. Such circuits are commonly employed to provide stabilised voltage supplies for other circuits. In the diagram of a simple stabilised power supply, a source of direct voltage is connected across a series circuit, comprising a resistance *A* and a junction diode *B*. Transistor *C* is assumed to be a p-n-p transistor. A semiconductor junction diode *D* is connected between the emitter electrode and the base electrode of the transistor. Diode *B* is of the type known as a Zener diode and is operated in its Zener-region so as to provide a source of reference voltage. The application of the invention to this circuit concerns the inclusion of the diode *D*. The diode is so chosen that under normal operating



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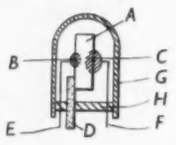
conditions it passes only a very small current compared with the normal base current of the transistor. The presence of diode *D* therefore scarcely affects the circuit behaviour under normal conditions. In the absence of diode *D* a short circuit in the output of the circuit would result in application of a relatively large voltage between the emitter and base of transistor *C*. This voltage might damage the internal emitter-base junction but would in general cause an excessive collector current to flow and thus result in destruction of the transistor. If, however, a suitably chosen diode *D* is included and the output terminals are then short circuited, the diode conducts strongly and shunts the Zener diode *B*, but limits the base-emitter voltage of the transistor to a value which does not result in the collector current rising to a catastrophically large value. The maximum value of the diode *D* voltage and hence of the base-emitter voltage of the transistor is determined by the diode characteristic and by the current through the diode and hence by the resistance *A*. By suitable choice of this resistance the maximum current through the diode *D* may be limited to such a value that this diode is also undamaged. The arrangement is fast in operation and can be used to protect transistors for which a conventional fuse-like or cut-out device would be too slow to be effective. On removal of the short-circuit the circuit returns immediately to its normal condition and requires no re-setting or replacement of components such as fuse-links.—*July* 26, 1961.

873,539. May 9, 1960.—SEMICONDUCTOR DEVICES, Standard Telephones and Cables, Ltd., Connaught House, 63, Aldwych, London, W.C.2. (*Inventors : Robert Anthony Hyman and Donald Gordon Neal Hunter.*)

In order to take full advantage of stores made from superconducting elements the devices used to provide access to them must themselves be capable of working at high speeds. It is also advantageous if they can be operated at low temperatures, in which case they can be placed in the bath with the store or at a relatively small temperature difference from the helium bath, thus reducing the heat transferred to the bath. There then is no need for large numbers of interconnecting wires from the low temperature enclosure up to room temperature. This last requirement not only rules out the use of conventional valves but also means that transistors made from silicon or germanium, which do not retain their properties at such low temperatures, are of no use. Accordingly the present invention provides an arrangement including an indium antimonide transistor and means for cooling this transistor to a temperature below 100 deg. K. The transistor shown in the drawing below is of the n-p-n type, having a base region *A* of p-type conductivity and emitter and collector regions *B* and *C* of n-type material. Cadmium is used as the doping element for producing the base region and tellurium for the emitter and collector regions. The base region is mounted on a copper member *D*, which also serves as a means for making connection to this part of the device, whilst copper connecting wires *E* and *F* are connected to the emitter and collector regions. The whole is sealed into a glass envelope *G* by means of a sealing member *H*. In operation the transistor is immersed in a liquid helium bath together with other similar devices and a store composed of a large number of superconductive switching elements. Indium antimonide has a very small energy gap and does not exhibit a transistor action at room temperature owing to the large number of thermally generated



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charge carriers present in the material. As the temperature is lowered the number of these carriers decreases, however, and at temperatures below about 150 deg. K their number is sufficiently small for the effect of charge carriers supplied by the doping elements to be of importance. The material can therefore be used as a transistor at these low temperatures. A further important property of indium antimonide is that one set of charge carriers, the electrons, have a much higher mobility than is found for either electrons or holes in silicon or germanium. This means that an indium antimonide transistor of given base width is capable of working at frequencies as high as those of the silicon or germanium device of much narrower base width. The possibility of achieving the same high frequency properties, and hence switching speeds, without requring such narrow base widths greatly simplifies the manufacture of the device.—*July* 26, 1961.

AIRCRAFT

873,679. October 6, 1959.—AIRCRAFT, The English Electric Company, Ltd., Queens House, 28, Kingsway, London, W.C.2. (*Inventors : Raymond Frederick Creasey, Bernard Oliver Heath and Geoffrey Francis Sharples.*)

The object of the present invention is to provide an aircraft suited both for use as a fighter and as a bomber, that is to say, having supersonic performance at altitude and the capability of low level bomber or attack performance at high speed with freedom from undue susceptibility to being affected by wind gusts together with good endurance or range, technical reliability, and short take-off and landing distance. These objects are achieved by providing the aircraft with twin engines of ample power to give the supersonic and take-off performance and still to give adequate range at cruise in spite of being then throttled back. The engines are placed towards the rear of and within the fuselage with jet pipes above and between the halves of an all-moving tailplane to avoid jet interference with tailplane surfaces, and in positions near the centre line of the fuselage so as to avoid undue thrust asymmetry when flying on a single engine. The aircraft services and performance are arranged so that the aircraft will fly safely on a single engine. A thin delta wing is used mounted high on the fuselage with a large blown flap provided along the whole free length of its trailing edge. This combination of wing, blown flaps and ample engine power provides adequate lift for short take-off and landing performance without undue reduction in engine thrust since only a modicum of blowing air is required. The delta wing plan form also enables a medium wing loading to be used giving supersonic manoeuvrability at high altitude without unduly affecting the take-off and landing performances. Moreover the low lift slope inherent to a delta wing gives an acceptable level of gust response even with the medium wing loading. Further, having a centre of pressure towards the rear of the wing enables the aircraft's centre of gravity to be located at the forward end of the twin engines so that the undercarriage may be positioned underneath the engine bay. The convenient space forward of the centre of gravity for fuel tanks above the armaments bay and a space for fuel tanks below the rear jet pipe allow for use of intercommunicating fuel tanks which give a balance in pitch at all fuel states. Owing to its wing plan form the aircraft is less susceptible to movement by wind gusts than is a high aspect ratio rectangular wing, and also the wing structure may be thinner and therefore suited to supersonic flying without weight penalty.—*July* 26, 1961.

Catalogues and Brochures

AVICA EQUIPMENT, Ltd., Mark Road, Hemel Hempstead, Hertfordshire.—Brochure describing flexible joints for insertion in ducting systems to relieve, control and contain stresses resulting from system expansions, relative movements and static and dynamic pressure end loads. Bellows assemblies, which are used mainly as expansion joints or flexible connections in rigid tube pipelines or ducting systems, are also described.

IMPERIAL ALUMINIUM COMPANY, Ltd., P.O. Box 216, Witton, Birmingham, 6.—Folder describing "Impalco" aluminium alloy treadplate. This is supplied in two different designs, the first embodying grouped projections set at right angles, and the second a diamond lattice pattern to Admiralty specifications. The ⅝in wide lattice stands proud of the main surface to an approximate height of 0·050in. Both designs give a non-slip surface.

SCOTT BADER AND CO., Ltd., Polyester Division, Wollaston, Wellingborough, Northamptonshire.—The 1961 edition of the company's Polyester handbook contains 129 pages, and includes an index, a glossary of terms, a bibliography and chapters giving an introduction and describing general characteristics of plastics, chemistry, curing and general formulations, reinforcements, a list of products, mould release agents, gel coats, methods of fabrication, applications, design considerations, quality control, visible flaws and common defects, machining, finishing and repair, and properties.

DOWSON AND MASON, Ltd., Alma Works, Levenshulme, Manchester, 19.—Bulletin No. 13/1A, "Forge, Bar, Tube and Plate Furnaces." This illustrated publication describes a large range of gas, solid fuel and oil-fired furnaces covering many requirements in the hot working or manipulation of ferrous metals. The equipment listed ranges from single and double chamber and slot furnaces for drop forges to large furnaces for heavy ingot reheating. Some special furnaces are included; heating equipment for bar and tube bending operations, for example, gas-fired hearths of the blacksmiths' type, and superheater tube bending furnaces.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Wed., Aug. 30.—PORTSMOUTH AND DISTRICT BRANCH : Royal Air Force Association Club, Cosham, Portsmouth, "Lighting," A. D. Charters, 7.30 p.m.

Fri., Sept 1.—LIVERPOOL AND DISTRICT BRANCH : Industrial Development Centre, M.A.N.W.E.B., Paradise Street, Liverpool, 1, Chairman's Address, J. R. Atkinson, 7.30 p.m.

INSTITUTE OF PHYSICS AND THE PHYSICAL SOCIETY

Thurs. and Fri., Sept. 21 *and* 22.—Department of Physics, University College of North Wales, Bangor, Joint conference on "Radiospectroscopy of Solids," Guthrie Lecture to be delivered during the conference—"The de Haas-van Alphen Effect and the Electronic Structure of Metals," D. Shoenberg.

Thurs. and Fri., Sept. 28 *and* 29.—ELECTRONICS GROUP : Assembly Room, Town Hall, Leamington Spa, Joint conference on "The Physics of Gas Discharge Devices."

INSTITUTION OF ELECTRICAL ENGINEERS

Wed. to Fri., Sept. 6 *to* 8.—ELECTRONICS AND COMMUNICATIONS SECTION : Savoy Place, London, W.C.2, Conference on "Microwave Measurement Techniques."

INSTITUTION OF MECHANICAL ENGINEERS

Tues. and Wed., Sept. 5 *and* 6.—SCOTTISH GRADUATES' SECTION : Autumn Conference in Scotland.

Thurs., Sept. 14.—LUBRICATION AND WEAR GROUP (EASTERN BRANCH AREA) : Social Club, Hoffmann Manufacturing Company, Ltd., Chelmsford, "Lubricants in Nuclear Reactors," P. E. B. Vaile, 7.30 p.m.

INSTITUTION OF PLANT ENGINEERS

Tues., Sept. 5.—LONDON BRANCH : Royal Society of Arts, John Adam Street, Adelphi, Strand, London, W.C.2, "Corrosion—Prevention by Cathodic Protection," R. A. Lowe, 7 p.m.

Wed., Sept. 6.—LEICESTER BRANCH : Grand Hotel, Leicester, "Gas in Industry," L. A. Lush, 7.30 p.m.

Tues., Sept. 12.—EDINBURGH BRANCH : 25, Charlotte Square, Edinburgh, Members' Evening, 7.30 p.m.

Wed., Sept. 13.—WESTERN BRANCH : Royal Clarence Hotel, Exeter, Film, "The Hinkley Point Power Station," 7 p.m.

Thurs., Sept. 14.—NORTH EAST BRANCH : Roadway House, Oxford Street, Newcastle-upon-Tyne, 1, "Insurance and the Plant Engineer," J. H. Oswald, 7 p.m.★GLASGOW BRANCH : Scottish Building Centre, 425, Sauchiehall Street, Glasgow, C.2, "Electronic Control of Machine Tools and Production Plant," 7.15 p.m.

SOCIETY OF INSTRUMENT TECHNOLOGY

Wed., Sept. 13.—EAST MIDLANDS BRANCH : College of Technology, Ashby Road, Loughborough, One-day conference on "The Application of Instrumentation in Industry with Special Reference to the Problems of the Small Firm," 9.30 a.m.

Advanced Engineering Courses

Mathematical Programming. THE UNIVERSITY OF BIRMINGHAM, Institute for Engineering Production, "Southfield," 56, Norfolk Road, Edgbaston, Birmingham, 15. The course is intended for members who are already familiar with the standard linear programming methods. It deals with more advanced techniques, which greatly extend the field to which programming may be applied. It is aimed at operational research workers, production planners and others who are concerned with programming problems. The course runs from Monday to Friday, September 25 to 29. Fee, covering course papers and all residential charges and meals, 35 guineas.

Corrosion Problems in the Electrical Power Industry. Eighth Summer School on Corrosion. BATTERSEA COLLEGE OF TECHNOLOGY, Metallurgy Department, London, S.W.11. The course, which runs from September 25 to 28, 1961, has been arranged in conjunction with the Corrosion Group of the Society of Chemical Industry and will deal with corrosion as it affects each stage in the generation of electrical power. "Introduction," E. C. Potter ; "Furnace-side Corrosion," W. D. Jarvis ; "High Temperature Water-side Corrosion," E. C. Potter ; "Corrosion of Cooling Surfaces," P. J. Gilbert ; "Corrosion of Feedline Surfaces," J. T. Harrison ; "Corrosion of Turbines," M. G. Gemmill ; "Corrosion in Transmission and Distribution," H. G. Masterson ; "Boiler Feedwater," H. J. Fortune. It is hoped to arrange a visit to Central Electricity Research Laboratories, Leatherhead, on Thursday, September 28. Fee £10, inclusive of luncheon, morning and afternoon refreshment.